TSG

TSG R0004-2009

Supervision Regulation on Safety Technology for Stationary Pressure Vessel

Issued on 2009-08-31 **Enforced on 2009-12-1**

General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China

Acknowledgements and additional note

On August 31st 2009, the General Administration of Quality Supervision, Inspection and Quarantine issued bulletin (No. 83) and promulgated *"Supervision Regulations on Safety Technology for Stationary Pressure Vessel"* and is enforced on December 1st 2009. In order to meet the demands of international trade for pressure vessels to facilitate the evaluation of pressure vessel manufacture license and thereby enabling the international pressure vessel enterprise to familiarize and implement the essential safety requirements of pressure vessels in China, the Bureau of Safety Supervision of Special Equipment of the General Administration of Quality Supervision, Inspection and Quarantine entrusted China Special Equipment Inspection & Research Institute to organize the translation of English version of *"Supervision Regulation on Safety Technology for Stationary Pressure Vessel"* .

The English version of *"Supervision Regulation on Safety Technology for Stationary Pressure Vessel"* is translated by Beijing Sanba Technology & Trade Ltd. and reviewed & revised by Mr. Shou Binan, Mr. Xu Hongyi, Ms Qi Yuedi, Ms Xu Tong, and Miss Li Chenyu from China Special Equipment Inspection & Research Institute.

Formal statement: the General Administration of Quality Supervision, Inspection and Quarantine is responsible for the interpretation of the *"Supervision Regulation on Safety Technology for Stationary Pressure Vessel"*. The Chinese Version is the legal version. There is no legal implication for the documents provided here in foreign languages. It is only for the purpose of reference.

The Japanese version of *"Supervision Regulation on Safety Technology for Stationary Pressure Vessel"* is a volunteer translation by Beijing Sanba Technology & Trade Ltd. And reviewed & revised by Mr. Xu Hongyi from China Special Equipment Inspection & Research Institute. We are grateful to all the individuals who have contributed to the aforementioned translations.

For any question in translation, please contact China Special Equipment Inspection & Research Institute (http://www.csei.org.cn, email: jsfgb@csei.org.cn) or Beijing Sanba Technology & Trade Ltd. (http://www.bjsanba.cn, email:sanba008@126.com)

Preface

In May 2007, the Special Equipment Safety Supervision Administration (abbreviated as SESA hereinafter) of the General Administration of Quality Supervision, Inspection and Quarantine (abbreviated as AQSIQ, hereinafter) established the project plan to revise "*Supervision Regulation on Safety Technology for Stationary Pressure Vessel* "(abbreviated as SRSTSPV, hereinafter). In September 2007, the Technical Regulation Division of China Special Equipment Inspection and Research Institute (abbreviated as CSEI, hereinafter) established a Working Group of the formulation (revision) and held the first meeting in Beijing. On the meeting the Working Group discussed principles, important contents, key issues and outlines for formulating (revising) the SRSTSPV, concretely assigned responsibilities of the drafting work, and set down a time table for the outline. In November 2007, the Working Group held the second meeting in Beijing and announced the exposure draft of the SRSTSPV as results of discussion. SESA issued Announcement [2008] No.10 to request comments from primary sectors, relevant departments and organizations, experts and citizens. In May 2008, the Working Group held the third meeting in Suzhou, Jiangsu Province and delivered the regulation draft incorporating the collected opinions. During the formulation (revision), SESA also held several seminars to discuss major issues of the formulation (revision) for the SRSTSPV, and commissioned CSEI and China Association of Special Equipment Inspection to organize two symposiums in January 2008 and July 2008 respectively to discuss the revision of the non-destructive examination in the SRSTSPV. In August 2008, SESA submitted the revised draft to the Special Equipment Safety Technology Committee of AQSIQ for deliberation. By integrating the valuable suggestions and comments, the Working Group further modified the draft and came up with the new revision for approval. In October 2008, the draft for approval of the SRSTSPV was submitted to WTO/TBT for notification by AQSIQ. In April 2009, the Working Group responded to the advisory opinions from the WTO/TBT, held a meeting to finalize the SRSTSPV in Beijing in May 2009, and determined the final version for approval of the SRSTSPV. On August 31, 2009, the SRSTSPV was approved and published by AQSIQ.

The fundamental principles of the revision of the SRSTSPV include the following:

(1) Transform the SRSTSPV into a safety technical regulation of special equipments

(TSG);

(2) Establish the position of the SRSTSPV in the system of special equipment regulations and standards;

(3) Learn lessons from accidents;

(4) Emphasize the concept that rules of laws prescribe the essential safety requirements of special equipments;

(5) Solve the major problems in the SRSTSPV that may have greater impacts on the industry by the detailed research findings, data and research results;

(6) Reinforce the service management and emergency rescue preplans;

(7) Reflect the energy-save principle;

(8) Promote fabrications and facilitate enterprises;

(9) Take advantage of the advanced scientific and technological achievements those are favorable for scientific and technological developments;

(10) Incorporate the international development and Chinese special features;

(11) Coordinate with safety technical regulations for special equipments and technical standards.

To be consistent with various systems, related requirements and scientific terms prescribed in "*Regulations on safety supervision for special equipment*", the major body of Safety Supervision was converted to AQSIQ including different local departments of quality and technical supervision. In general, it retained the original outlines and the main contents of the original SRSTSPV, which demonstrating that rules of laws are the essential safety requirements in design, fabrication, installation, alternation, maintenance, service, inspection, and test of special equipment. These essential safety requirements are not involved technical details related to the product. In consistent with the current basic national policy of energy-saving, reducing pollutants discharging and energy consumption, the revised SRSTSPV has come up with some related basic requirements, such as, adjustments of safety factor, heat exchanger's thermal efficiency, thermal/cold insulation requirements, the proof pressure test for periodic inspections, and so on. In order to solve the classification for categories of pressure vessels, to introduce concepts of risks and failure modes, the classified supervision for pressure vessels based on the single vision are implemented, and the essential safety ideas are

highlighted. The applicable scope of the revised SRSTSPV is adjusted and covered all pressure vessels in the scope of "*Regulations on safety supervision for special equipment*" that were not subjected to the safety supervision in the original SRSTSPV. Meanwhile, the original version (1999) of "*Supervision Regulation on Safety Technology for Pressure Vessel*" is converted to "*Supervision Regulation on Safety Technology for Stationary Pressure Vessel"*. In addition, "*Supervision Regulation on Safety Technology for Transportable Pressure Vessel"* is formulated otherwise, and some recently issued supervision regulations regarding safety technology are temporarily retained that including pressure vessels such as super-high pressure vessels, simple pressure vessels, non-metallic pressure vessels, and so on. Some provisions with limitation are adjusted with some flexibility so as to facilitate the application of new materials, new processes and new technologies. A few unnecessary or outdated provisions, such as issues of the design pressure for liquefied gases, nonferrous metals, the expanding ratio of tubes, the re-examination requirements of materials, product welded test coupons, and so on, are accordingly adjusted. The risk-based inspection (RBI) technology, the Time of Flight Diffraction Technique (TOFD), and the evaluation methods for defects are introduced based on scientific and technological researches, and scientific and technological achievements. Unnecessary superfine data sheets are adjusted (deleted) and the product data sheet of pressure vessels is increased. The raised requirement of informational process laid down the foundations for the future information-based management.

The participants for formulating (revising) this Regulation listed as follows:

China Special Equipment Inspection and Research Institute: Shou Binan, Xie Tiejun, Jia Guodong, Zheng Hui, Qi Yuedi

Bureau of Safety Supervision of Special Equipment, AQSIQ : Wang Xiaolei, Li Jun, Chang Yanyan, Zhang Jianrong

Hefei General Machinery Research Institute: Chen Xuedong, Li Jingchen, Yuan Rong

China Standardization Committee on Boilers and Pressure Vessels: Qin Xiaozhong, Yang Guoyi

Shanghai Bureau of Quality and Technical Supervision: Tang Xiaoying

Zhejiang University: Zheng Jinyang

Special Equipment Safety Supervision Inspection Institute of Jiangsu Province: Miao

Chunsheng, Yuan Biao

Sinopec Engineering Incorporation: Li Shiyu, Zhang Yingkai

Jinzhou Heavy Machinery Co., Ltd.: Liu Jing

Sinopec Beijing Yanshan Petrochemical Co., Ltd.: Wang Guang

PetroChina Company Limited: Liu Nongji

Lanzhou Petroleum Machinery Research Institute: Zhang Yanfeng

China Association of Special Equipment Inspection : Wu Shengwu

China HuanQiu Contracting & Engineering Corporation: Ye Rixin

China Tianchen Engineering Corporation : Qu Jianping

Former Boiler & Pressure Vessel Safety Supervision Bureau, the Ministry of Labour: Song Hongming

China Special Equipment Inspection and Research Institute, China Standardization Committee on Boilers and Pressure Vessels, Special Equipment Safety Supervision Inspection Institute of Jiangsu Province and its branch in Suzhou, Hefei General Machinery Research Institute, China Association of Special Equipment Inspection, Zhejiang University and other units have performed significant amount of research and conference organizational work for the formulation (revision) of the SRSTSPV.

The SRSTSPV is translated by Beijing Sanba Technology & Trade Ltd (http://www.bjsanba.cn email:sanba008@126.com) Please contact us for any questions about this translation.

CONTENT

Supervision Regulations on Safety Technology for Stationary Pressure Vessels

1 General Requirement

1.1 Purpose

In order to ensure the safe operation of stationary pressure vessels, protect the safety of human life and property, and promote the development of national economy, this Supervision Regulations on Safety Technology for Stationary Pressure Vessels (abbreviated Regulation, hereinafter) is established in accordance with *"Regulations on Satety Supervision of Special Equipment"*.

1.2 Stationary pressure vessels

Stationary pressure vessels refer to pressure vessels installed and operated at fixed locations (hereinafter referred to as pressure vessels, see Note 1.1).

Note 1-1: Pressure vessels to be moved and/or used within the certain scope of the facility or plant field for a particular purpose, as well as air tanks in transportable air compressor units are jurisdicted by this regulation.

1.3 Applicable scope

This Regulation is applicable to stationary pressure vessels in conformity with all of the following conditions as a whole：

(1) The working pressure is equal to or greater than 0.1 MPa (Note 1-2);

(2) The product of working pressure and volume is equal to or greater than 2.5 MPa*L (Note 1-3);

(3) The medium is gas, liquefied gas or liquid which maximum working temperature is equal to or greater than its standard boiling point (Note 1-4).

In which, ultrahigh pressure vessels shall be in accordance with *"Super-high Pressure Vessel Safety and Technical Supervision Regulation"*; Nonmetal pressure vessels shall be in accordance with *"Nonmental Pressure Vessels Safety and Technical Supervision Regulation"*; simple pressure vessels shall be in accordance with *"Simple Pressure Vessels Safety and Technical Regulation"*.

Note 1-2 Working Pressure, refers to the maximum pressure (guage pressure) possibly occurred on the top of a vessel at normal working conditions.

Note 1-3 Volume, refers to the geometrical room of the pressure vessel, namely the volume calculated based on the dimensions of the design drawings and after roundness (tolerance is not considered). In general, the volume of the internals permanently amounted inside the pressure vessel could be deducted.

Note 1-4 This Regulation is also applicable to the vessel when the maximum operating temperature of the containing liquid lower than its standard boiling point, meanwhile, the product of the vapor space volume and the working pressure is equal to or greater than 2.5MPa*L.

1.4 Special provisions for applicable scope

Users shall be responsible for the safety management of their pressure vessels subject to this Article according to the service management provisions of this Regulation.

1.4.1 Pressure vessels satisfying the General Requirement, Design, and Fabrication only

Under the applicable scope of this Regulation, the following pressure vessels with volume no less than 25L are required to satify the provisions of only Chapter 1, Chapter 3 and Chapter 4.

(1) Air tanks for transportable air compressor units, for which *"Supervision Regulations on Safety Technology for Simplel Pressure Vessels"*are not applicable.

(2) Non-independent pressure vessels of cryogenic installations, pressure vessels of direct-fired absorption refrigeration equipments, aluminum plate-fin heat exchangers, and pressure vessels in cold boxes of air separating units.

(3) Jacketed heat exchangers, spiral plate heat exchangers, and brazing plate heat exchangers.

(4) Air compressed hydraulic tanks used for hydraulic auto-pneumatic water feeding devices (water feeding without tower), air and water feeding by air pressure (foam) compressed tanks used for extinguishing devices;

(5) Pressure vessels used for ion exchange or filtration precess in water treatment equipments, water expansion tanks used for hot-water boilers;

(6) Fully enclosed electric apparatus (capacitance pressure vessels) used for power industry only;

(7) Tire vulcanizers and pressed rubber moulds used in rubber industry;

(8) Accumulators affiliated to machines

1.4.2 Pressure vessels conforming to General Requirement, Design and Manufacture Licensing only

A pressure vessel with its volume greater than 1L and less than 25L or its inner diameter (for non-circular cross sections, refer to the maximum geometric dimension of the inside boundary in the crosssection, such as, the diagonal for a rectangle, the major axis for an ellipse) less than 150mm shall only satify the provisions in General Requirement, Article 3.1 and Article 4.1.1, and the design and fabrication shall satify the requirements of corresponding product standards.

1.4.3 Pressure vessels satisfying General Requirement and Manufacture licensing only

Pressure vessels with volume no greater than 1L shall satify General Requirement and Article 4.1.1 only; also, the design and fabrication of above vessels shall satify the corresponding product standards.

1.5 Non-applicable scope

This Regulation is not applicable to pressure vessels as following:

(1) Transportable pressure vessels, gas cylinders and hyperbaric oxygen chambers;

(2) Heat recovery boilers within the scope of the supervision regulations on safety technology for boilers;

(3) Vessels with normal operating pressure less than 0.1MPa (including vessels under instantaneous pressure no less than 0.1MPa during feeding or discharging processes);

(4) Pressure containers that are as integral parts or components of rotating or reciprocating mechanical devices, such as shell of pumps, shell of compressors, shell of turbines, hydraulic cylinders, etc;

(5) Disassemble spacer plate heat exchangers (including semi-weld plate heat exchangers), air-cooling heat exchangers and cooling pipes.

1.6 Definition of pressure vessel scope

The jurisdiction scope of this Regulation covers pressure vessel bodies and safety accessories of pressure vessels.

1.6.1 Body of the pressure vessel

The main body of a pressure vessle is defined as following:

(1) The bevel surface of the first circumferential joint between a pressure vessel and external

pipes or devices connected by welding, the first threaded joint with screwed connections, first flanged sealing surface with flanged connections and the first sealing surface with special connectors or pipe connectors;

(2) Pressure covers and their fasteners of the openings of pressure vessels;

(3) Connection welds between non-pressure parts and pressure vessels.

Main pressure components in a pressure vessel body include shells, heads(end plates), expansion joints, equipment flanges, petals of a spherical tank , tubesheets and tubes of a heat exchanger; main bolts greater than M36 (including M36) in specification, nozzle and pipe flanges with diameter no less than 250mm.

1.6.2 Safety accessories

Safety accessories of pressure vessels, include safety valves directly connected with pressure vessles, rupture disk devices, emergency shut-off devices, safety interlock devices, pressure gages, liquid level gages, and thermometric instruments, etc.

1.7 Catogeries of Pressure Vessels

Depending on the dangerous grade, pressure vessels applicable to this Regulation are classified into three categories so as to facilitate the supervision and administration.

See Annex A for classifications of pressure vessels.

1.8 Inter-relationship with technical standards and management rules

This Regulation specifies the essential safety requirements of pressure vessels. Involved technical standards and management rules of pressure vessels, as a minimum, shall satisfy the requirements of this Regulation.

1.9 The rule for handling inconformity to this Regulation

Provide pressure vessels constructed with new material, new technology, new process and/or its special service conditions not meet the requirements of this Regulation, involved enterprises/institutes shall submit the technical documentations involving the foundation, data, results, as well as inspection and testing reports of the design, research, and experiment to General Administration of Quanlity Supervision, Inspection and Quarantine of P.R.China (abbreviated AQSIQ). Technical organizations or technical institutes entrusted by AQSIQ shall carry out technical evaluations and assessments. When the results of evaluations and assessments are approved by AQSIQ, pressure vessels with new material, new technology or new process can

be put in trials for fabrication and service.

1.10 Quoted Standards

Main standards quoted in this Regulation are as follows (Note1-5):

(1) GB 150《Steel Pressure Vessels》;

(2) GB 151《Tubular Heat Exchangers》;

(3) GB 12337《Steel Spherical Tanks》;

(4) JB/T 4710《Steel Tower Tanks》;

(5) JB/T 4731《Steel Horizontal Tanks》;

(6) JB 4732《Steel Pressure Vessels- Design by Analysis》;

(7) JB/T 4734《Aluminum Welded Vessels》;

(8) JB/T 4745《Titanium Welded Vessels》;

(9) JB/T 4755《Copper Pressure Vessels》;

(10) JB/T 4756 《Nickel and Nickel Alloy Pressure Vessels》.

Note 1-5: For standards quoted in this Regulation with the year note, both their amendent sheets (not including contents of corrections) and revisions do not apply to this Regulation. Ones without the year note, their latest versions apply to this Regulation.

1.11 Supervisory administration

(1) The design, fabrication (including field assebly welding, same as below), installation, alteration, maintenance, service, inspection, and testing of pressure vessels shall implement the provisions of this Regulation accordingly;

(2) All parties involved with the design, fabrication, installation, alteration, maintenance, service, inspection, and testing of pressure vessels shall follow the related regulation of information management for special equipment, and input required data into the information systems in time;

(3) AQSIQ and local quality technical supervision departments are in charge of the safety supervision of pressure vessels as well as monitoring the implementation of this Regulation.

2 Material

2.1 General requirement

(1) Mechanical properties, chemical properties, physical properties and process

properties shall be considered when selecting materials for pressure vessels;

(2) The quality, specification and identification mark of materials used for pressure vessels shall conform to the requirements of corresponding National Standards or Industrial Standards, and other requirements on their use shall conform to the provisions of quoted standards in this Regulation;

(3) Steel Mills of plates (strips) specially used for pressure vessels shall obtain the corresponding Special Equipment Manufacture License;

(4) Steel Mills shall make clear and solid hard stamp or identification marks by other measures at conspicuous locations of the material, steel Mills who hold the special equipment manufacture license shall mark the identification of manufacture license and the number of the license also;

(5) Steel Mills shall provide the material quality certificate to manufacturers. The content of the material quality certificate shall be complete and clear, and stamped with quality inspection by steel Mills;

(6) For steel plates specially used for pressure vessels, when materials are supplied directly by steel Mills to pressure vessel manufacturers, the number of copies of the material quality certificate is determined by both sides; when materials are provided by a supplier other than steel Mills, the steel Mills shall provide the material quality certificate for each plate respectively;

(7) When the pressure vessel manufacturer obtain materials not from steel Mills for the pressure vessel, an original material quality certificate provided by the steel Mill or a copy of document with an inspection stamp of the material supplier and a manager's stamp are required (except steel plates specially used for pressure vessels); the pressure vessel manufacturer is responsible for the authenticity and consistency of material quality certificates of pressure vessel materials.

2.2 Smelting methods

The steel used for pressure parts of pressure vessels shall be killed steel smelted by basis oxygen or electric furnace process. For low alloy steel plates and austenite-ferrite stainless steel plates with the specified tensile strength low limit equal to or greater than 540 MPa, and the low temperature steel plates and low temperature steel forgings generally used for design temperature lower than -20℃, an additional out-of-furnace refining process is required.

2.3 Chemical composition (heat analysis)

2.3.1 Carbon steels and low alloy steels used for welded structure

Carbon steels and low alloy steels: C≤0.25％, P≤0.035％, S≤0.035％.

2.3.2 Carbon steels and low alloy steels specially used for pressure vessels

The content of Phosphor and Sulfur of carbon steels and low alloy steels (steel plates, steel tubes and forgings) of specially used for pressure vessels shall satisfy the requirements as following:

(1) Essential requirement for carbon steels and low alloy steels: P≤0.030%, S≤0.020%;

(2) For steel materials with the specified tensile strength low limit ≥540MPa, P≤0.025%, S≤0.015%;

(3) For steel materials, used at design temperature lower than -20℃ and their specified tensile strength low limit < 540MPa, P≤0.025%, S≤0.012%;

(4) For steel materials, used at design temperature lower than -20℃ and their specified tensile strength low limit ≥540MPa, P≤0.020%, S≤0.010%.

2.4 Mechanical properties

2.4.1 Impact energy

For steel plates with thickness not less than 6mm, tubes with the diameter and thickness capable to 5mm sub-size impact specimen, and forgings of any size, the impact energy (KV_2) of V-notch specimen under the temperature of the designed impact test shall meet the requirements in Table 2-1.

Table 2-1 Impact Energy of Carbon Steel and Low Alloy Steel
(Steel Plate, Steel Tube and Steel Forging), (Note 2-1)

Specified Tensile Strength Low Limit R_m (MPa)	Mean Impact Energy of Three Standard Specimens *KV2* (J)
≤450	≥20
＞450～510	≥24
＞510～570	≥31
＞570～630	≥34
＞630～690	≥38

Note 2-1:

(1) The interception location and method of a specimen shall conform to the specifications of the related steel standard.

(2) Three standard specimens (10 mm in width) shall be tested for each group of impact test. It is allowed that one of individual specimens' impact energy values is lower than those listed in above table, but cannot be lower than 70% of the value.

(3) When steel material sizes are not sufficient for preparing standard specimens, sub-size impact specimens with width of 7.5mm and 5mm shall be prepared in turn, and the impact energy for them shall be 75% and 50% of that for standard specimens, respectively.

(4) For the steel material with its impact energy value required in the steel standards higher than that in Table 2-1, the provisions of the relevant steel standards shall be followed either.

2.4.2 Elongation

(1) For steel plates, steel tubes and steel forgings for pressure components of pressure vessels, their elongation shall conform to the applicable requirements of quoted standards in this Regulation and the corresponding steel standards.

(2) For plates of carbon steesls, low alloy high-tensile steels and low alloy low temperature steels used for welded structure, the elongation value (A) shall meet the requirements in Table 2-2;

(3) The elongation values between different specimens dimensions shall be converted according to GB/T 17600.1 *"Conversion of steel elongation, part 1: carbon steels and low alloy steels"* and GB/T 17600.2: *"Conversion of steel elongation, part 2: austenite steels"*. The converted values shall meet the requirements of this Article.

Table 2-2 Elongation of Steel Plate (Note 2-2)

Specified Tensile Strength Low Limit Rm (MPa)	Elongation A (%)
≤420	≥23
＞420～550	≥20
＞550～680	≥17

Note 2-2: If the specified elongation value in the steel plate standard is greater than that in Table 2-2, the elongation value shall conform to the steel plate standard.

2.5 Ultrasonic test (UT) for steel plates

2.5.1 Test requirement

For plates of carbon steels and low alloy steels with thickness equal to or thicker than 12mm (except layered plates of wrapped layered pressure vessels) used for shells of pressure vessels, the ultrasonic test shall be conducted on each plate when it meets the conditions listed below:

(1) Pressure vessels for containing extremely or highly toxic mediums;

(2) Pressure vessels used in wet H_2S corrosive environment;

(3) Pressure vessels with design pressure equal to or higher than 10MPa;

(4) Steel plates requiring UT for each plate as specified in quoted standards of this Regulation.

2.5.2 Acceptance quality criteria of UT

The UT of plates shall be conducted according to JB/T 4730 *"Nondestructive Testing of Pressure Equipment"*. For steel plates meet the requirements specified in item (1) to (3) of Article 2.5.1, the acceptance quality criteria shall not be less than Class II. For steel plates meet the requirements specified in item (4) of Article 2.5.1, the acceptance quality criteria shall be in conformity with the provisions of quoted standards in this Regulation.

2.6 Cast irons for pressure vessels

2.6.1 Application limitation for cast irons

Cast irons shall not be used for pressure components of pressure vessels containing extremely, highly or moderately toxic mediums, and containing explosive mediums with the design pressure equal to or higher than 0.15MPa. It shall not be used for pressure components of tubular waste-heat boilers. Except above pressure vessels, the following cast iron materials can be used.

(1) Grey cast irons: HT200, HT250, HT300 and HT350;

(2) Nodular graphite cast irons: QT400-18R and QT400-18L.

2.6.2 Limitation of design pressure and design temperature

(1) For grey cast irons, the design pressure shall not be higher than 0.8MPa and the design temperature range is 10℃~200℃;

(2) For nodular graphite cast irons, the design pressure shall not be higher than 1.6MPa, the design temperature range is 0~300℃ for QT400-18R, and -10℃ ~300℃ for QT400-18 L.

2.7 Nonferrous materials for pressure vessels

2.7.1 General requirement

Nonferrous materials for pressure vessels (i.e. aluminum, titanium, copper, nickel and their alloys) shall satisfy the requirements as following:

(1) Technical requirements of nonferrous materials shall be in accordance with the provisions of quoted standard in this Regulation. The Additional requirements, if necessarily, shall be prescribed on design drawings or indicated in corresponding technical specifications;

(2) Manufacturers of pressure vessels shall establish the strict storage system, and set specific areas to separate nonferrous materials from carbon and low alloy steels.

2.7.2 Aluminum and aluminum alloys

When used for pressure components of pressure vessels, aluminum and aluminum alloys shall satisfy the requirements as following:

(1) The design pressure shall not be higher than 16MPa;

(2) The design temperature range shall be -269~65℃ for aluminum alloys with the magnesium content equal to or greater than 3% (e.g., 5083 and 5086), and -269~200℃ for other aluminum and aluminum alloys.

2.7.3 Copper and copper alloys

When used for pressure components of pressure vessels, the design temperature of the pure copper and brass shall be lower than 200℃.

2.7.4 Titanium and titanium alloys

When used for pressure components of pressure vessels, titanium and titanium alloys shall satisfy the requirements as following:

(1) The design temperature shall not be higher than 315℃ for titanium and titanium alloys, and not be higher than 350℃ for titanium-steel clad plates;

(2) Titanium and titanium alloys used for shells of pressure vessels shall be used under the annealed condition.

2.7.5 Nickel and nickel alloys

Nickel and nickel alloys used for pressure components of pressure vessels shall be used under the annealed or the solid solution condition.

2.7.6 Tantalum, zirconium, niobium and their alloys

When used for pressure components of pressure vessels, tantalum, zirconium, niobium and their alloys shall be used under the annealed condition. The design temperature shall not be higher than 250℃ for tantalum and its alloy, not be higher than 375℃ for zirconium and its alloy, and not be higher than 220℃ for niobium and its alloy.

2.8 Clad steel plates

Clad steel plates used for pressure vessels shall be selected according to the specifications of quoted standards in this Regulation, and shall satisfy the requirements as following:

(1) The shear strength of the bonded interface of clad steel plates shall not be less than 210MPa for stainless steel and steel, not be less than 210MPa for nickel and steel, not be less than 140MPa for titanium and steel, and not be less than 100MPa for copper and steel;

(2) The service condition of the base material for the clad steel plate shall conform to the specifications of quoted standards in this Regulation;

(3) For the base material of the carbon steel and low alloy steel (including steel plate and steel forging), the impact test shall be conducted according to base material standards, and the impact energy value shall conform to base material standards or provisions of the purchase contract.

2.9 The use of foreign designate materials

2.9.1 Materials produced by manufacturers outside P.R. China

(1) Foreign designate materials shall be the ones currently being allowed for the pressure vessel based on respective current pressure vessel codes and standards, and also have been sound experienced in service. The application scope shall conform to specifications of respective standards for corresponding products. If foreign designate materials have similar chemical composition and mechanical properties as listed in quoted standards, the application scope of the foreign designate materials shall also satisfy the quoted standards in this Regulation;

(2) Technical requirements of foreign designate materials shall not be less than those of domestic similar materials (such as contents of S and P, interception location, sampling direction and impact energy value, elongation, etc.);

(3) Material quality certificates and identification marks on materials shall conform to provisions of Article 2.1 of this Regulation;

(4) Manufacturers of pressure vessels shall review and verify incoming materials and material quality certificates, and re-examine the chemical composition and mechanical properties of materials to meet related requirements prior to using;

(5) While materials used for pressure components of welded pressure vessel structure, manufacturers of pressure vessels shall conduct the welding procedure qualification based on the welding performance of the material prior to the first application;

(6) For the steel with specified tensile strength low limit equal to or greater than 540MPa, and the low alloy steel used for pressure vessels with the design temperature lower than -40℃, material manufacturers shall apply for a technical evaluation and assessment and get approval according to Article 1.9 of this Regulation before the material is allowed to be in use.

2.9.2 Materials produced by domestic manufacturers

Foreign designate materials produced by domestic Mills shall not only conform to the

requirements in Article 2.9.1 of this Regulation, but also shall apply for a technical evaluation and assessment and get approval according to the requirements of Article 1.9 in this Regulation. The contents of the evaluation and assessment include the related condition of the Mill and technical documents about the trial material.

2.9.3 Selection of foreign designate materials

If the Designer selects foreign designate materials, necessity and economy of the material selection shall be adequately explained in the design document.

2.10 Use of new materials

2.10.1 Materials not listed in quoted standards of this Regulation

When materials not listed in quoted standards are to be adopted for main pressure components of pressure vessels, the Mills shall carry out systematically experimental research before the trial production, and shall apply for the technical evaluation and assessment and get approval according to Article 1.9 of this Regulation prior to using.

2.10.2 Materials listed in quoted standards of this Regulation

For the steel listed in GB 150 or JB 4732, with the specified tensile strength low limit equal to or greater than 540 MPa, and the low alloy steel used for pressure vessels with design temperature lower than -40℃, if the steel Mill does not have achievement in the field of pressure vessel construction, the Mill shall carry out systematically experimental research, and then apply for the technical evaluation and assessment and get approval according to Article 1.9 of this Regulation prior to using.

2.11 Materials usage and identification mark transfer

(1) The manufacturer of pressure vessels shall ensure the materials used for pressure vessels to be in conformity with this Regulation by the way of investigation, evaluation and tracing on the material suppliers, and verify the material quality certificates and material marks while the material receiving;

(2) For the grade IV forging purchased for the category III pressure vessel, and/or the material used for main pressure components of which the authenticity of material quality certificate is uncertain or the mechanical properties and chemical composition are doubtful, the manufacturer of pressure vessels shall conduct re-examination on the material. The material can only be put into fabrication while it conforms to the provisions of this Regulation;

(3) The identification marks on materials for pressure components of pressure vessels shall be transferred prior to cutting.

2.12 Welding consumables

(1) For welding materials used for pressure parts of pressure vessels, the mechanical properties of the filler metal shall be equal to or higher than the specified values for the base metal; other properties of the filler metal shall not less than corresponding requirements of the base meal when necessary;

(2) Welding consumables shall meet the requirements of standards for corresponding welding consumables and the quoted standards in this Regulation, and the supplier shall provide the quality certificates of welding consumables with clearly and solidly tagged labels;

(3) The pressure vessel manufacturer shall set up and strictly implement procedure of receiving, re-examination, preservation, drying, delivery and reclamation for welding consumables.

2.13 Material substitute

When a pressure vessel manufacturer or a site assembly welding company intends to use substitute materials for main pressure components, the written approval shall be provided from the original Designer in advance, and the corresponding record shall be prescribed on the as-built drawing in detail.

3 Design

3.1 License and responsibility of Designer

(1) The Designer shall be responsible for the design quality, and their licensing, the categories of design licenses, variety and scope for pressure vessels shall conform to the provisions of *"Design Appraisal Regulations for Pressure Vessel and Pressure Pipe"*;

(2) For the Designer who uses design-by-rules for overall design but partially refer design-by-analysis for pressure components of pressure vessels may not hold the design licenses of stress analysis;

(3) The design of pressure vessels shall conform to the essential safety requirements of this Regulation. For pressure vessels designed by international standards or codes outside P.R. China, the Designer shall provide documents which declare the design has satisfied the essential safety requirements specified in this Regulation;

(4) The Designer of pressure vessels shall provide complete design documents to the design entrusting party.

3.2 Design licensing stamp

(1) A design licensing stamp of the pressure vessel (a copy of stamp is invalid) shall be sealed on the assembly drawing of the pressure vessel. The design drawings sealed the invalid design licensing stamp or as-built stamp shall not be used for fabrication;

(2) The name of the Designer shown on the design licensing stamp shall be consistent with the name stamped on the drawings.

3.3 Design specification

The design entrusting party shall provide the formal design specification of the pressure vessel to the Designer in written. The design specification shall include the following at minimum:

(1) Operating parameters (including working pressure, working temperature range, liquid level height, load on nozzle, etc.);

(2) The location and natural conditions for the pressure vessel service (including ambient temperature, seismic fortification intensity, loads of wind and snow, etc);

(3) Composition and properties of medium;

(4) Estimated service life;

(5) Geometric parameters, nozzle location and orientation;

(6) Other necessary specifications for the design.

3.4 Design documents

3.4.1 General requirement

(1) The design documents of pressure vessels include strength calculation sheets or stress analysis reports, design drawings, manufacturing technical specification, risk assessment report (applicable for category III pressure vessels). When the Designer deemed necessary, the installation, operation, and maintenance instructions shall also be included;

(2) When pressure vessels is equipped with safety valves or rupture disk devices, the design documents shall also include the calculation sheets of safety relieving capacity of pressure vessels, the discharge capacity of safety valves and the relieving area of rupture disks. If these calculations cannot be done, the pressure relief devices shall be selected by consultation with the design entrusting party or the User.

3.4.2 Assembly drawing

3.4.2.1 Review and approval of assembly drawing

The assembly drawing shall be reviewed and approved in accordance with the requirements of related safety technical regulations. For category III pressure vessels, an

approval signature of the technical responsible personnel or his / her authorized person of the pressure vessel Designer shall be signed on the assembly drawing.

3.4.2.2 Main content of the assembly drawing

The assembly drawing of pressure vessels shall include the following at minimum:

(1) Name and category of pressure vessels, regulations and standards for the design and manufacture;

(2) Working condition, including working pressure, working temperature, toxicity of medium, explosion damage degree, etc;

(3) Design condition, including design temperature, design loads (including pressure and all sorts of loads to be considered), medium (composition), corrosion allowance, welding joint efficiency and natural condition etc; filling ratio for tanks containing liquefied petroleum gas; limited content of corrosive medium for storage pressure vessels with material having stress corrosion tendency;

(4) Material designations and corresponding standards for main pressure components;

(5) Main characteristic parameters (such as pressure vessel volume, heat transfer area and pass number of heat exchanger etc);

(6) Design service life of pressure vessels (cycle number for vessels requiring fatigue analysis);

(7) Special requirements for fabrication;

(8) Requirements for heat treatment;

(9) Requirements for nondestructive examination;

(10) Requirements for proof pressure test and leak test;

(11) Requirements for corrosion-proof;

(12) Safety accessories specifications and particular purchase requirements (except considered in the process system);

(13) Location of the pressure vessel nameplate;

(14) Requirements for packing, transportation, field-assembly welding and installation.

3.4.2.3 Particular requirements

The particular requirements for assembly drawing are needed for the following situations:

(1) For pressure vessels with multiple chambers, the test pressure of each pressure chamber shall be indicated individually. The allowable pressure difference between two sides of the shared parts, and the test procedure and requirements shall be indicated where special requirements existing;

(2) For pressure vessels filled with catalysts and fillings, the technical requirements for periodic inspection in service shall be indicated;

(3) For pressure vessels incapable of internal inspections due to the structural reason, the calculated thickness and the requirements for periodic inspection in service shall be indicated;

(4) For pressure vessels incapable of proof pressure tests, the calculated thickness and special requirements for fabrication and operation shall be indicated;

(5) For pressure vessels with the thermal-isolation lining, the requirements for technical measures of preventing pressure components from over-heating shall be indicated;

(6) For pressure vessels with the heat or cold insulation, the corresponding measures shall be provided.

3.5 Design method

The design-by-rules or the design-by-analysis can be used for the design of pressure vessels. When necessary, the experimental method or the empirical design method can also be used after applied the technical evaluation and assessment and got approval in accordance with the provisions of Article 1.9 in this Regulation.

Based on the design specification in Article 3.3 of this Regulation, the Designer of pressure vessels shall consider comprehensively all related factors, failure modes and safety margin, to ensure the strength, rigidity, stability and corrosion resistance of pressure vessels are sufficient. In the same time, the Designer shall also consider the strength requirements of the welded joints between the main body of pressure vessels and skirts, legs, lifting lugs, etc, to ensure the safety of pressure vessels in design service life.

3.6 Risk evaluation

For category III pressure vessels, the Designer shall provide a risk evaluation report which included main failure modes, risk control, etc.

3.7 Requirements for energy-saving

In the design of pressure vessels, the principles of energy-saving and consumption reduction shall be fully considered. The design shall meet the requirements as the following:

(1) The economy of pressure vessels shall be fully considered to select the material and the structural size appropriately;

(2) For heat exchangers, the design shall be optimized to increase efficiency of heat exchanging and to satisfy the requirement of energy efficiency;

(3) For pressure vessels with thermal/cold insulation requiments, effective thermal/cold insulation measures for pressure vessels shall be stated in the design documents.

3.8 Safety factor

The minimum safety factor for the allowable stress (or the design stress intensity) of materials shall be determined in accordance with the provisions specified in Table 3-1~Table 3-3. When the safety factor is below the provisions specified, it shall conform to the provisions of Article 1.9 in this Regulation.

Table 3-1 Safety Factors of Design-by-Rules Method

Material（Plate, Forging and Pipe）	Safety factors			
	Tensile Strength at Room Temperature R_m	Yield Strength at Design Temperature R^t_{eL}（$R^t_{p0.2}$）（Note 3-1）	Mean Endurance Strength at Design Temperature R^t_D（Note 3-2）	Mean Creep Limit at Design Temperature (with Creep Rate 0.01% per 1000h) R^t_n
Carbon Steel and Low Alloy Steel	n_b≥2.7	n_s≥1.5	n_d≥1.5	n_n≥1.0
High Alloy Steel	n_b≥2.7	n_s≥1.5	n_d≥1.5	n_n≥1.0
Titanium and Alloys	n_b≥2.7	n_s≥1.5	n_d≥1.5	n_n≥1.0
Nickel and Alloys	n_b≥2.7	n_s≥1.5	n_d≥1.5	n_n≥1.0
Aluminum and Alloys	n_b≥3.0	n_s≥1.5	—	—
Copper and Alloys	n_b≥3.0	n_s≥1.5	—	—

Note 3-1: If $R^t_{p1.0}$ is allowed in quoted standards, it can be used for the calculation of the allowable stress.

Note 3-2: According to the design service life, the value of endurance strength may be selected among 1.0×10^5h, 1.5×10^5h, 2.0×10^5h, etc.

Table 3-2 Safety Factors of Design-by-Analysis Method

Material	Safety Factors	
	Tensile Strength at Room Temperature R_m	Yield Strength at Design Temperature R^t_{eL}（$R^t_{p0.2}$）（Note 3-3）
Carbon Steel and Low Alloy Steel	n_b≥2.4	n_s≥1.5
High Alloy Steel	n_b≥2.4	n_s≥1.5

Note 3-3: If $R^t_{p1.0}$ is allowed in quoted standards, it can be used for the calculation of the allowable stress.

Table 3-3 Safety Factors of Stud (Bolt)

Material	Stud (Blot) Diameter (mm)	Heat Treatment Conditions	Safety factors	
			Yield Strength at Design Temperature R^t_{eL}（$R^t_{p0.2}$）	Average of Endurance Strength at Design Temperature R^t_D
Carbon Steel	≤M22	Hot Rolled, Normalized	2.7	1.5
	M24～M48		2.5	
Low Alloy Steel and Martensitic High Alloy Steel	≤M22	Quenched Plus Tempered	3.5	
	M24～M48		3.0	
	≥M52		2.7	
Austenite High Alloy Steel	≤M22	Solid Solution	1.6	
	M24～M48		1.5	

The safety factor for the tensile strength of grey cast irons at room temperature shall be not less than 10.0. The safety factor for the tensile strength of nodular graphite cast irons at room temperature shall be not less than 8.0.

3.9 Pressure

3.9.1 Design pressure and calculated pressure

(1) Design pressure is defined as the maximum set pressure at the top of the vessel and shall be applied as the conditions of design load with the corresponding design temperature. The design pressure shall not be less than the working pressure;

(2) Calculated pressure is defined as the pressure used to determine the thickness of the parts with the coincident design temperature. It shall take consideration of additional loads such as the static head pressure of liquid, etc.

3.9.2 Set pressure of pressure relief devices

(1) For pressure vessels equipped with pressure relief devices, the set pressure of pressure relief devices shall not be higher than the design pressure of pressure vessels;

(2) For pressure vessels, of which the maximum allowable working pressure is indicated on design drawings, the set pressure shall not be higher than the maximum allowable working pressure.

3.9.3 The design pressure for the pressure vessel containing liquefied gas at ambient

temperature

The design pressure for the pressure vessel containing liquefied gas at ambient temperature shall be determined as the following based on the working pressure at specified temperature:

(1) The design pressure for the pressure vessel containing liquefied gas at ambient temperature shall be not less than the specified value as indicated in Table 3-4;

Table 3-4 Working Pressure at Specified Temperature for Pressure Vessels Containing Liquefied Gas at Ambient Temperature

<table>
<tr><td rowspan="3">Critical temperature of liquefied gas</td><td colspan="3">Working Pressure at Specified Temperature</td></tr>
<tr><td rowspan="2">without Insulation</td><td colspan="2">with Insulation</td></tr>
<tr><td>without Temperature Actually Measured by Test</td><td>with Maximum Operating Temperature Actually Measured by Test, and Ensuring it Less Than Critical Temperature</td></tr>
<tr><td>≥50℃</td><td>Saturated Vapor Pressure at 50℃</td><td colspan="2">Saturated Vapor Pressure at Probable Maximum Operating Temperature</td></tr>
<tr><td>＜50℃</td><td colspan="2">Gas Pressure at 50℃ under Maximum Filling Weight Specified by Design</td><td>Saturated Vapor Pressure at Actually Measured Maximum Operating Temperature by Test</td></tr>
</table>

(2) The working pressure at specified temperature for the pressure vessel containing liquefied petroleum gas at ambient temperature shall be determined by the actual saturated vapor pressure of the mixed composition of liquefied petroleum gas at the temperature not less than 50℃. The Designer shall prescribe the limited composition and the corresponding pressure on the drawings. When the actual composition data is unavailable or the composition analysis is not made, the working pressure at specified temperature shall be not less than the specified value as indicated in Table 3-5.

Table 3-5 Working Pressure at Specified Temperature for Pressure Vessels Containing Mixed Liquefied Petroleum Gas at Ambient Temperature

<table>
<tr><td rowspan="2">Saturated Vapor Pressure of Mixed Liquefied Petroleum Gas at 50℃</td><td colspan="2">Working Pressure at Specified Temperature</td></tr>
<tr><td>without Insulation</td><td>with Insulation</td></tr>
<tr><td>≤Saturated Vapor Pressure of Isobutene at 50℃</td><td>Saturated Vapor Pressure of Isobutene at 50℃</td><td>Saturated Vapor Pressure of Isobutene at Probable Maximum Operating Temperature</td></tr>
<tr><td>>Saturated Vapor Pressure of Isobutene at 50℃
≤Saturated Vapor Pressure of Propane at 50℃</td><td>Saturated Vapor Pressure of Propane at 50℃</td><td>Saturated Vapor Pressure of Isobutene at Probable Maximum Operating Temperature</td></tr>
<tr><td>>Saturated Vapor Pressure of Propane at 50℃</td><td>Saturated Vapor Pressure of Propylene at 50℃</td><td>Saturated Vapor Pressure of Isobutene at Probable Maximum</td></tr>
</table>

		Operating Temperature

3.10 Temperature

(1) Design temperature is defined as the set metal temperature of the pressure part under normal operating conditions of the pressure vessel, i.e. average of metal temperature along the cross section of the pressure part. The design temperature shall be as the conditions of design load with the coincident design pressure;

(2) When designing storage pressure vessels at ambient temperature, the impact of atmospheric environment temperature on shell metal temperature of pressure vessels under normal working conditions shall be fully taken into consideration. The minimum design temperature shall not be greater than the average minimum temperature of the month over the years. It may be calculated by the sum of the minimum temperature for each day of that month divided by total days of that month.

3.11 Corrosion allowance

For pressure vessels with uniform corrosion, the corrosion allowance shall be determined by the estimated service life and the material corrosive rate with the involved medium. In the meantime, the impact of abrasion and erosion due to medium flow shall also be taken into consideration for pressure components.

3.12 Minimum thickness

The minimum thickness of pressure vessels shall be determined by taking consideration of the impact of manufacture, transportation, installation, etc.

3.13 Filling ratio

The design storage capacity of pressure vessels containing liquefied gas shall be specified and the filling ratio shall not be greater than 0.95.

3.14 Weld joint

3.14.1 Design of shell joint

The full penetration welded butt joints shall be used for longitudinal joints of cylinders, circumferential joints of cylinder-to-cylinder (or cylinder-to-head) connection, spliced joints of a head and welded joints of petal-to-petal of a spherical tank. Petals of a spherical tank shall not be spliced.

3.14.2 Design of joint between nozzle and shell

For steel pressure vessels, the design for nozzle (flange)-to-shell joints, and jacketed pressure vessel joints may refer to the quoted standards of this Regulation. The full penetration weld joint shall be used if any of the following cases may occur:

(1) Pressure vessels containing inflammable and extremely or highly toxic mediums;

(2) Pressure vessels requiring the pneumatic test or pneumatic-hydraulic combination test;

(3) Category III pressure vessels;

(4) Low temperature pressure vessels;

(5) Pressure vessels designed by fatigue analysis;

(6) Directly fired pressure vessels;

(7) Pressure vessels particularly specified on design drawings.

3.15 Joint efficiency

(1) For welded pressure vessels, the reduction of the material strength by weld joints shall be considered. The joint efficiency shall be determined according to the corresponding quoted standards;

(2) It is not allowed to exempt nondestructive examination of pressure vessels by decreasing joint efficiency.

3.16 Requirements of nondestructive examination

The Designer of pressure vessels shall specify the nondestructive examination method, percentage, the quality requirements and acceptable quality criterion, etc on design drawings according to the provisions of this Regulation, quoted standards and JB/T 4730.

3.17 Nozzle flanges of pressure vessels

(1) For steel pressure vessels, the design for nozzle flange, gasket and fastener shall refer to the specifications of industrial standards HG/T 20592~HG/T 20635-2009 "*Steel Nozzle Flange, Gasket, Fastener"*;

(2) For pressure vessels containing liquefied petroleum gas, extremely or highly toxic mediums and moderately toxic mediums with strong penetrability, the design of nozzle flange shall conform to the specifications of industrial standards HG/T 20592 ~ HG/T 20635, and at least shall use the combination of long welding neck flanges, spiral-wound gaskets with reinforcing rings and high strength blots at special grade.

3.18 Inspection openings

(1) Inspection openings including manholes and hand holes shall be set on pressure vessels when necessary. The location, amount and size of the inspection openings shall satisfy the requirements of internal inspection;

(2) For pressure vessels incapable or unnecessary of setting inspection openings, the Designer shall provide specific technical measures such as increasing the items or percentage of inspection in manufacture, and shall specify requirements about key inspection items, methods of periodic inspection in service.

3.19 Telltale hole of opening reinforcement ring

For the reinforcement ring of the opening on the pressure vessel and the backing having reinforcing function with continuous weld along periphery, at least one leakage telltale hole shall be set.

3.20 Quick opening pressure vessels

Pressure vessels with the quick opening closure are ones with quick seal locking devices mutually nested with each other between the main body and the head or end plate of the in-and-out path. Bolts connected vessels (such as swing bolts) do not belong to quick opening pressure vessels. The impact of fatigue load shall be taken into consideration for the design of pressure vessels with the quick opening closure.

Pressure vessels with the quick opening closure shall have safety interlock functions that meet following requirements:

(1) Operation for pressure cannot be started unless the quick opening closure reaching the preset shut position;

(2) The quick opening closure cannot be opened until internal pressure of the pressure vessel completely being released.

3.21 Non-detachable thermal isolation

For pressure vessels with the thermal isolation, if the isolation is unallowable being detached in design, the requirements for the periodic inspection items and methods in service shall be prescribed in the design documents. When necessary, the particular requirements of full nondestructive examination on all welded joints shall be prescribed on the drawings either.

3.22 Particular requirements of corrosion-resistant

For pressure vessels or pressure parts that have particular requirements of corrosion-resistant, for example those in corrosion medium condition with inter-granular corrosion, stress corrosion, pitting corrosion, crevice corrosion, etc, the corresponding testing methods of corrosion resistance and necessary heat treatment shall be prescribed on design drawings.

3.23 Water quality

For fired and continuously operated pressure vessels with water as medium (including tubular waste-heat boilers), the water quality shall satisfy the specifications of GB 1576-2008 *"Water Quality for Industrial Boiler"*.

3.24 Leak test

For pressure vessels containing extremely or highly toxic medium and being permitted for no least leakage, the leak test requirement of pressure vessels shall be prescribed on design drawings.

For cast iron pressure vessels containing gaseous medium, the requirement for airtight test of pressure vessels shall be prescribed on design drawings for manufacture.

For pressure vessels with pressure relief devices i.e. safety valves, rupture disks, etc, if the airtight test required in design documents, the maximum allowable working pressure shall be provided by the Designer.

4 Fabrication

4.1 General requirement

4.1.1 Manufacturer

(1) The pressure vessel manufacturer (including field-assembly welding, hereinafter) shall obtain the special equipment manufacturing license, and fabricate within the approved scope, establish and implement effectively the quality control system in accordance with the requirements of relevant rules of laws, and safety technical regulations. The legal representative of manufacturer must be responsible for the quality of pressure vessels;

(2) Manufacturers shall strictly enforce the relevant rules of laws, safety technical regulations and corresponding standards, and fabricate and assembly welding pressure vessels in accordance with the design documents.

4.1.2 Type test (Prototype test)

Pressure vessels requiring type tests such as accumulators shall pass through type(prototype) tests taken by the approved type test institute of the AQSIQ and obtain certificates for type(prototype) tests.

4.1.3 Fabrication supervisory inspection

Pressure vessel manufacturers shall accept the supervisory inspection during their manufacturing process by the special equipment inspection and testing institute.

4.1.4 Product delivery documentation

4.1.4.1 General requirement

Manufacturers shall provide Users with following technical documentations as a minimum when they delivery pressure vessels:

(1) As-built drawings, the as-built drawing shall be with the design licensing stamp (duplication of stamp is invalid) and a finish seal, including the manufacturer name, the manufacturing license number, a signature of review person and the sign of "As-built Drawing". If anything happened during fabrication, such as material substitution, change of nondestructive examination method or change of final size etc, the manufacturer shall clearly make indications on the as-built drawings in accordance with the requirements in the written approval document from the Designer with the signature of the person who makes changes

and the date of changes at the indication column;

(2) Pressure vessel conformity certificate, including Product Data Sheet, see sample in Annex B, product quality certification documents (including material quality certificates of the main pressure components, material list, quality plan or inspection & testing plan, checking report of structure dimensions, weld map, nondestructive examination report, heat treatment report and automatically recorded curves, proof pressure test report and leak test report, etc) and a rubbing or a copy of the product's nameplate;

(3) Supervisory inspection certificate of special equipment (applicable to the products where supervisory inspection are conducted);

(4) Pressure vessel design documents specified in Article 3.4 of this Regulation.

4.1.4.2 Product delivery documentations of heads and forgings

Manufacturers of pressure components for pressure vessels such as heads and forgings shall provide quality certificate documents of the pressure components to Purchasers.

4.1.4.3 Completion files for field-assembly welding

When the field-assembly welded pressure vessel is completed and accepted, the installation company shall provide the technical documents of assembly welding and quality inspection to the User in addition to the technical documents and information specified in Articles 4.1.4.1 and 4.1.4.2 of this Regulation.

4.1.5 Product nameplate

Product nameplates shall be located in a conspicuous place on vessels. The nameplate shall be written in Chinese (in both Chinese and English when necessary) and SI unit (the format of product nameplate is in Annex C). The contents of the product nameplate shall at least include the following:

(1) Product name;

(2) Name of manufacturer;

(3) License number and level of manufacture licensing;

(4) Product standards;

(5) Materials of main body;

(6) Medium name;

(7) Design temperature;

(8) Design pressure, maximum allowable working pressure (when necessary);

(9) Pressure of proof pressure test;

(10) Product serial number;

(11) Equipment code (numbering method of special equipment code is in Annex D);

(12) Date of manufacture;

(13) Pressure vessel category (according to Annex A of this Regulation, which is divided into categories I, II and III);

(14) Volume (heat transfer area).

4.1.6 Design changes

When the manufacturer intends to change the original design, a written document of agreement for the change shall be obtained from the original Designer. All the changes shall be recorded in details.

4.2 Welding

4.2.1 Welding Procedure Qualification

The requirements of pressure vessel welding procedure qualifications are as follows:

(1) Before pressure vessel products are welded, welded joints of pressure components, welds to pressure components, tack welds that melt in permanent welds, welding overlay and welding repair on the base metal of pressure components, as well as welding repair of all welds mentioned above shall go through welding procedure qualifications or be supported by qualified welding procedure specifications (WPS);

(2) The pressure vessel welding procedure qualification shall conform to the requirements of JB 4708 *"steel pressure vessel welding procedure qualification"*;

(3) The supervisory inspector shall supervise the process of the welding procedure qualification;

(4) Upon completion of the welding procedure qualification, the welding procedure qualification record (PQR) and the welding procedure specification (WPS) shall be reviewed by the responsible welding engineer of the manufacturer (assembly welding company) , approved by the technical chief of the manufacturer, signed and confirmed by the supervisory inspector, and finally archived in technical files;

(5) The technical file of the welding procedure qualification shall be kept as long as the expiry date of the welding procedure qualification, the specimens of the welding procedure qualification shall be kept for at least 5 years.

4.2.2 Welder and Welder identification

(1) Welders engaged in welding operation of pressure vessels (referred to as welders

hereinafter), shall be qualified in accordance with the provisions of related safety technical regulations, and hold the personnel certificate of special equipment operator prior to welding within the scope of applicable terms before the expire date;

(2) The welder shall perform welding in accordance with the welding procedure specification (WPS) or welding working instructions and take the field welding records. The inspector of the manufacturer shall check the actual welding parameters;

(3) The welder's symbol shall be stamped at the specified place adjacent to the weld of the pressure component or record the welder's identification in the weld map (including welds layout drawing). The weld map shall be included in the product quality certification documents;

(4) The manufacturer shall create the technical records for welders.

4.2.3 Fabrication and assembly of pressure vessels

Forced assembly is not allowed and the use of cross weld is not recommended on pressure vessels.

4.2.4 Welding repair

The requirements of welding repair (including welding repair of base metal defects) are as follows:

(1) The cause of defect shall be analyzed, and the appropriate procedure for welding repair shall be presented;

(2) The welding procedure qualification of welding repair shall be carried out in accordance with the Article 4.2.1 of this Regulation, or it shall be supported by qualified welding procedure specifications (WPS). Welding repair shall be recorded in detail;

(3) It's not recommended to carry out welding repair exceed twice at the same position, or else, the welding repair shall be approved by the technical chief of the Manufacturer before welding, and the number of repair, position and situations of welding repair shall be recorded in the quality certification documents;

(4) For the pressure vessel requiring postweld heat treatment to relieve stress, generally, the welding repair shall be performed prior to heat treatment. In case of the welding repair after heat treatment, whether the stress relief heat treatment is necessary shall depend on the depth of welding repair for defects;

(5) For pressure vessels or pressure components with particular requirements on corrosion

resistance, the corrosion resistance shall be kept not less than original requirements after welding repair;

(6) The position of welding repair shall be re-examined and accepted in accordance with the original requirements.

4.3 Test coupon (plate) and specimen

4.3.1 Pressure vessels requiring preparation of the product welded test coupon

(1) Carbon steel and low alloy steel pressure vessels under low temperature service;

(2) Low alloy steel pressure vessels with specified tensile strength low limit equal to or greater than 540MPa;

(3) Steel pressure vessels which heat treatment are required to improve or restore the mechanical properties;

(4) Pressure vessels containing extremely or highly toxic medium as specified on design drawings;

(5) Pressure vessels which the product welded test coupon is required on design drawings and/or quoted standards of this Regulation.

4.3.2 The preparation requirements for the product welded test coupon.

(1) The product welded test coupon shall be at the extension portion of the cylindrical longitudinal weld, and shall be welded simultaneously with the cylindrical longitudinal weld (except for spherical pressure vessels and forged-welded pressure vessels);

(2) The raw material of the test coupon shall be acceptable, and shall be of the same material standard, same designation, same thickness, and same heat treatment condition as those of the vessel;

(3) The test coupon shall be done by the welder who welds the pressure vessel with the same condition and same welding procedures as the pressure vessel;. For the pressure vessel with the requirement of heat treatment, the test coupon shall generally be heat-treated together with the pressure vessel. Otherwise, special measures shall be taken to ensure that the test coupon is heat-treated in the same process as pressure vessel;

(4) Based on the material, thickness, structure, and welding procedure of the pressure vessel, the manufacturer shall decide the quantity of the welded test coupon prepared for each pressure vessel in accordance with the design drawings and the requirements of quoted standards of this

Regulation.

4.3.3 The preparation requirements for heat-treatment test coupon of the base metal

(1) When the specified heat treatment condition of the base metal in service are the same as that in delivery, if the heat treatment condition is altered in the manufacturing process, re-heat treatment is required;

(2) The heat treatment is used for the material mechanical property improvement in the manufacturing process.

When preparing above heat-treatment test coupon of a base metal, if the product welded test coupon is required also, one combination test coupon is allowed.

4.3.4 Examination requirements of mechanical properties for both product welded test coupon and heat treatment test coupon of the base metal.

Specimens of the product welded test coupon and the heat treatment test coupon of the base metal for the pressure vessel shall subject to mechanical examinations in accordance with the following requirements:

(1) The type, quantity, interception and preparation of specimens shall conform to the design drawings and the specifications of quoted standards in this Regulation;

(2) The test methods, test temperatures, acceptance criteria and re-test request of mechanical examination shall be in accordance with design drawings and quoted standards of this Regulation;

(3) When the test coupon is unacceptable, it shall be disposal in accordance with the specifications of quoted standards in this Regulation.

4.3.5 Preparation requirements for the corrosion resistance test coupon and specimen

(1) For pressure vessels or pressure components requiring the corrosion resistance test, the corrosion resistance test coupon shall be prepared, the cutting of specimens, quantity, type, size, machining and testing methods of specimens, and the criteria of test results shall conform to the design drawings and specifications of corresponding test standards;

(2) For stainless steel and nickel alloy pressure vessels requiring the inter-granular corrosion sensitivity test, their test coupons and specimens shall conform to the specifications of GB/T 21433 *"Inter-granular Corrosion Sensitivity Test of Stainless Steel Pressure Vessel"* or JB/T 4756, and meet the requirements of design drawings.

4.4 Requirements of visual examination

4.4.1 The appearance and geometric dimensions of cylindrical shells and heads

The main examination items on appearance and geometry dimensions of shells and heads are as follows, whereas examination methods and acceptance criteria are according to design drawings and the requirements of quoted standards in this Regulation:

(1) The main geometric dimensions, nozzle location and orientation;

(2)Abrupt rigid-or-valley and alignment offset of longitudinal and girth welds in the single wall cylinder (including the inner shell of the wrapped layered pressure vessel and the integrally wrapped pressure vessel), the spherical shell and head;

(3) The loose area of the wrapped layered pressure vessel and the integrally wrapped pressure vessel, the clearance between the shrink surface of the shrink-fit pressure vessel;

(4) The inner dimension tolerance of the convex head, and the knuckle radius of the torispherical head and toriconical head;

(5) Shape and dimensions of the circular shaped top plate and petals of the spherical vessel;

(6) The transition size of the butt joint with unequal thicknesses.

4.4.2 Surface quality of welded joints

(1) The surface shall be free of various defects such as surface cracks, incomplete penetrations, incomplete fusions, surface porosities, arc craters, incomplete filled grooves, and visible slag inclusions etc;

(2) The weld shall have a smooth transition to the base metal;

(3) The shape of the fillet weld shall be in concave transition smoothly;

(4) For pressure vessels designed by fatigue analysis, the weld reinforcement for longitudinal and girth welds shall be ground flush with the base metal;

(5)The undercut and other surface quality shall conform to the design drawings and specifications of quoted standards in this Regulation.

4.5 Nondestructive examination

4.5.1 Nondestructive examination personnel

The nondestructive examination personnel shall be qualified in accordance with the relevant technical regulations to obtain a corresponding personnel certificate. And then they can take charge of the nondestructive examination in correspondence with the NDE method and Level in the certificate.

4.5.2 Nondestructive examination methods

(1) The methods of nondestructive examinations for pressure vessels include radiographic test, ultrasonic test, magnetic particle test, liquid penetration test and eddy current test, etc;

(2) The pressure vessel manufacturer or the nondestructive examination institute shall establish nondestructive examination procedures of pressure vessels according to the requirements of design drawings and the specifications of JB/T 4730;

(3) When the nondestructive examination method is not included or exceed the applicable scope of JB/T 4730, it shall be in accordance with the provisions of Article 1.9 in this Regulation.

4.5.3 Nondestructive examination of welded joints for pressure vessels

4.5.3.1 The selection of nondestructive examination methods

(1) For butt-welded joints of pressure vessels, the radiographic test or ultrasonic test shall be performed, ultrasonic test includes the Time of Flight Diffraction Technique (TOFD), the recordable and un-recordable Ultrasonic Pulse-echo Method; when using un-recordable Ultrasonic Pulse-echo Method, radiographic test or TOFD shall be used as a spot examination additionally;

(2) The radiographic test shall be preferably used for the welded joints of nonferrous pressure vessels;

(3) The magnetic particle test or liquid penetration test shall be carried out for fillet welds of nozzles or pipes seat, welded joints of tube-to-tubesheet, welded joints of the dissimilar steel, and the welded joints with the reheat cracking tendency and the delayed cracking tendency;

(4) The magnetic particle test shall be preferably used for welded joints of pressure vessels made of magnetic ferrite material.

4.5.3.2 Percentage of nondestructive examination

4.5.3.2.1 Essential percentage requirements

The percentage of nondestructive examination for butt welded joints of pressure vessels is generally divided into two kinds: full (100%) and spot (equal to or greater than 20%) examinations. For carbon steel and low alloy steel pressure vessels under low temperature service, the percentage of the spot nondestructive examination shall be equal to or greater than 50%.

4.5.3.2.2 The full examination by radiographic test or ultrasonic test

Categories A and B butt-welded joints of pressure vessels (the classification of Categories A

and B butt-welded joints of pressure vessels is in accordance with the specification of GB 150) shall be performed the full (100%) nondestructive examination with the method specified in the item (1) of Article 4.5.3.1 in this Regulation for one of the following conditions:

(1) The category Ⅲ pressure vessels with design pressure equal to or greater than 1.6 MPa;

(2) Pressure vessels fabricated by standards of design-by-analysis;

(3) Pressure vessels requiring pneumatic test or pneumatic-hydrostatic combination test;

(4) Pressure vessels with welded joint efficiency of 1.0 or pressure vessels incapable of internal inspection in service;

(5) For a low-alloy steel pressure vessel with specified tensile strength low limit is equal to or greater than 540MPa, when the thickness is greater than 20mm, additional spot nondestructive examination shall be performed with the method specified in the item (1) of Article 4.5.3.1 in this Regulation. The spot nondestructive examination shall cover all intersecting portions of welds with the different method from the full nondestructive examination;

(6) When required by design drawings and quoted standards of this Regulation.

4.5.3.2.3 Spot radiographic test or ultrasonic test

Each Categories A or B butt-welded joints of pressure vessels which are not required full nondestructive examination shall be performed the spot nondestructive examination with the item (1) of Article 4.5.3.1 in this Regulation for the following requirements:

(1) The location of the spot nondestructive examination shall be specified by the manufacturer based on the actual situation, but it shall include the intersecting portions of the Categories A and B welds and the welds to be covered by other components;

(2) When the unacceptable defect occurs at the welded joint by the spot nondestructive examination, a supplementary spot examination of the length not less than 250mm of the same welded joint shall be performed from both ends of the defect. If the result still fails to meet the criteria, a 100% examination shall be conducted on that welded joint.

For pressure vessels with the spot nondestructive examination, the Manufacturer shall still be responsible for the quality of welds which are not performed any nondestructive examination.

4.5.3.3 The timing for performing nondestructive examination

(1) The visual inspection of shape, dimension and exterior of the pressure vessel welded joints shall be performed to meet the criteria prior to nondestructive examination;

(2) The nondestructive examination for welded heads shall be performed after forming. If the nondestructive examination is performed prior to forming, then a nondestructive re-examination shall be conducted from the knuckle to the straight section of the formed head;

(3) For the material having delayed cracking tendency, the nondestructive examination shall be performed at least 24 hours after welding; for the material having reheat cracking tendency, an additional nondestructive examination shall be performed after heat treatment;

(4) For the low-alloy steel pressure vessel with specified tensile strength low limit is equal to or greater than 540MPa, the magnetic particle test or liquid penetration test shall be performed on welded joints after the proof pressure test.

4.5.3.4 The technical requirements for nondestructive examination

4.5.3.4.1 The technical requirements of radiographic test technology

Radiographic test shall be performed in accordance with the specification of JB/T 4730, the quality requirements and acceptable quality criterion are as follows:

(1) For butt-welded joints requiring full nondestructive examination, the radiographic test technology level shall not be lower than Class AB, the acceptable quality criterion shall not be lower than Class Ⅱ;

(2) For butt-welded joints requiring spot nondestructive examination, the radiographic test technology level shall not be lower than Class AB, the acceptable quality criterion shall not be lower than Class III, and incomplete penetration welding is not permitted;

(3) For fillet joints and T-shaped joints, the radiographic test technology level shall not be lower than Class AB, the acceptable quality criterion shall not be lower than Class Ⅱ.

4.5.3.4.2 Technical requirements for ultrasonic test

Ultrasonic test shall be performed in accordance with the specification of JB/T 4730, quality requirements and acceptable quality criterion are as follows:

(1) For butt-welded joints requiring full nondestructive examination, the technical level of Ultrasonic Pulse-echo Method shall not be less than Class B, the acceptable quality criterion shall be Class Ⅰ;

(2) For butt-welded joints requiring spot nondestructive examination, the technical level of Ultrasonic Pulse-echo Method shall not be less than Class B, the acceptable quality criterion shall not be less than Class Ⅱ;

(3) For fillet joints and T-shaped joints, the technical level of Ultrasonic Pulse-echo Method shall not be less than Class B, the acceptable quality criterion shall be Class Ⅰ;

(4) For welded joints tested by the Time of Flight Diffraction Technique (TOFD) method, the acceptable quality criterion shall not be less than Class Ⅱ.

4.5.3.4.3 Requirements of combination examination technology

When combination of radiographic test and ultrasonic test used, the quality requirements and acceptable quality criterion shall conform to the specification of standards for radiographic test and ultrasonic test respectively, and both acceptable quality criteria shall be met.

4.5.3.4.4 Technical requirements for surface nondestructive examination

The magnetic particle test or liquid penetration test of all pressure vessel welded joints shall be performed in accordance with the specification of JB/T 4730, and the acceptable quality criterion is as follows:

(1) For steel pressure vessels tested by magnetic particle or liquid penetration, the acceptable quality criterion shall be Class I;

(2) For non-ferrous pressure vessels tested by liquid penetration, the acceptable quality criterion shall be Class I.

4.5.3.5 Nondestructive examination requirements for nozzle welded joints.

(1) For butt welded joints of pressure vessel nozzles with nominal diameter equal to or greater than 250mm, the nondestructive examination methods, percentage and the acceptable quality criterion shall be the same as that for welded joints of the main body;

(2) For butt welded joints of pressure vessel nozzles with nominal diameter less than 250mm, the nondestructive examination methods, percentage and the acceptable quality criterion shall be in accordance with the design drawings and the specifications of quoted standards in this Regulation.

4.5.4 Nondestructive examination requirements of raw materials and parts.

Nondestructive examination methods, percentage, and the acceptable quality criteria of raw materials and parts shall be in accordance with design drawings and the specifications of quoted standards in this Regulation.

4.5.5 Records, information, and reports of nondestructive examination

Manufacturers shall fill in nondestructive examination records truthfully, issue the

nondestructive examination reports correctly, and well preserve the examination information such as radiographic films and ultrasonic test data (including the record before defects repairing), set up NDE files of pressure vessel products, the preservation period shall not be less than 7 years.

4.6 Postweld heat treatment

4.6.1 General requirement

The postweld heat treatment for pressure vessels and pressure components shall conform to the design drawings and provisions of quoted standards in this Regulation. When the stress relief methods other than the postweld heat treatment are used, the provisions of the Article 1.9 in this Regulation shall be followed.

The postweld heat treatment shall be performed after the welding and inspection are fully completed. The postweld heat treatment shall meet the following requirements:

(1) Before the proof pressure test;

(2) When the requirement specified on design drawings and provisions of quoted standards in this Regulation, the postweld heat treatment procedure shall be set up before heat treatment. The specific process requirements of heat treatment shall be proposed for the field heat treatment;

(3) The heat treatment equipment (furnace) is furnished with thermometers of automatic curve records, and the time versus temperature curve shall be plotted.

4.6.2 Postweld heat treatment of austenitic stainless steel pressure vessels and non-ferrous pressure vessels

Postweld heat treatment is generally not required for austenitic stainless steel pressure vessels and non-ferrous pressure vessels.

If heat treatment is necessary for special requirements, it shall be specified on design drawings.

4.7 Proof pressure Test

4.7.1 Type of proof pressure test

Proof pressure test shall be performed after the pressure vessel is fabricated. Proof pressure tests include three types, i.e. hydrostatic test, pneumatic test and pneumatic-hydrostatic combination test.

4.7.2 Test pressure

The test pressure shall meet the requirements of design drawings, and shall not be less

than the value calculated by (4-1):

$$p_T = \eta p \frac{[\sigma]}{[\sigma]^t} \qquad (4\text{-}1)$$

Where:

p_T — Test pressure，MPa；

η — Pressure factor of proof pressure test，obtained from Table4-1；

P — Design pressure of the pressure vessel or the maximum allowable working pressure specified on the nameplate of the pressure vessel（for the pressure vessel in service, generally taken as the operating pressure），MPa;

$[\sigma]$ — Allowable stress of material at test temperature（or design stress intensity），MPa;

$[\sigma]^t$ — Allowable stress of material at design temperature（or design stress intensity），MPa

When the components of the pressure vessel (such as shell, head, nozzle and flange etc.) are made of different materials, the test pressure shall be calculated with the minimum value of $[\sigma] / [\sigma]^t$ for the materials of each component.

Table4-1 Pressure Factor of Proof Pressure Test η

Pressure Vessel Material	Pressure Factor of Proof Pressure Test	
	Hydrostatic Test	Pneumatic Test and Pneumatic-Hydrostatic Combination Test
Steel and Nonferrous Metal	1.25	1.10
Cast Iron	2.00	—

4.7.3 Strength verification of the pressure vessel in proof pressure test

When the test pressure is higher than that specified in this Regulation, strength verification of the shell shall be performed in accordance with the specifications of quoted standards in this Regulation.

4.7.4 Preparations of proof pressure test

(1) All the fastening bolts at various connecting locations of the pressure vessel shall be completely mounted and properly tightened prior to proof pressure test;

(2) The pressure gages used for test shall conform to the corresponding provisions of Chapter 8 of this Regulation. At least two calibrated pressure gages with the same measuring range shall be used and installed at the top of tested vessel for easy observation;

(3) During proof pressure test, the appropriate measures for temporary pressure parts welded on the pressure vessel shall be taken to ensure the strength and safety;

(4) The reliable safety protection measures shall be provided at the site of proof pressure test, and be identified and accepted by the technical chief and the safety department of the manufacturer.

4.7.5 General requirements for proof pressure test

(1) During the holding period, any action of continuously raising pressure to keep the pressure constantly is not allowed. During proof pressure test process, the bolts shall not be tightened and any external force shall not be applied on pressure components;

(2) During the proof pressure test, any unrelated work is not allowed, and any unrelated personnel shall not stay at the testing site;

(3) During the proof pressure test, the supervisory inspector shall be present on site for supervisory inspection;

(4) After the proof pressure test, if the welding repair is performed because of the welded joint leak or the nozzle leak, or the repairing depth greater than 1/2 the thickness of the vessel, one more proof pressure test shall be conducted.

4.7.6 Hydrostatic test

4.7.6.1 Requirements of hydrostatic test

(1) Any liquid having no risk in test may be used as the hydrostatic test medium at the temperature less than the boiling point of that liquid. When an inflammable liquid is used as the hydrostatic test medium, the test temperature shall be less than the flash point of that liquid; and any fire source shall be far away from the test site. Some necessary fire fighting equipments shall be provided at the test site;

(2) When water used as the hydrostatic test medium, the water quality shall be in accordance with design drawings and specifications of quoted standards in this Regulation. After the test is

acceptably completed, the water-based stain in the vessel shall be cleaned off immediately;

(3) The tested pressure vessel shall be fully filled with testing liquid. Any gas in the pressure vessel shall be purged out completely. And the outer surface of the pressure vessel shall be kept dry;

(4) When the wall metal temperature of the pressure vessel is close to liquid temperature, the pressure in testing may be raised up to the design pressure gradually. After no leakage is identified, the pressure in testing shall be continuously raised up to the specified test pressure, and be held for a sufficient time. Then the pressure is relieved to the design pressure, and is held a sufficient time for inspection. During inspection, the pressure shall be kept constant;

(5) During hydrostatic test, the test temperature (the wall metal temperature of the vessel) shall be 30℃ higher than the nil ductility transition temperature of the vessel metal, or be in accordance with the specifications of quoted standards in this Regulation. If the nil ductility transition temperature of the material is raised due to the plate thickness etc, the testing temperature shall be increased correspondingly;

(6) The hydrostatic test procedure for heat exchangers shall conform to the specifications of quoted standards in this Regulation.

(7) For a new pressure vessel, the inside shall be dried up by compressed air after hydrostatic test.

4.7.6.2 Acceptance criterion of hydrostatic test

The hydrostatic test of the pressure vessel is acceptable when all the following conditions are met:

(1) No leakage;

(2) No visible deformation;

(3) No unusual noise during testing.

4.7.7 Pneumatic test

When the testing liquid cannot be filling into the pressure vessel due to the reason of structure or support; or even a little amount of residual liquid in the pressure vessel is not permitted due to operating requirements, a pneumatic test may be used in accordance with the prescription on design drawings.

4.7.7.1 Requirements of pneumatic test

(1) The testing gases shall be dry and clean air, nitrogen or other inert gases;

(2) During pneumatic test, the test temperature (the wall metal temperature of vessel) shall be 30℃ higher than the nil ductility transition temperature of the vessel metal, or be in accordance with the specifications of quoted standards in this Regulation. If the nil ductility transition temperature of the material is raised due to the plate thickness etc, the testing temperature shall be increased correspondingly;

(3) During testing, the safety department of the manufacturer shall supervise on testing site;

(4) During testing, the pressure shall be gradually raised to 10% of the specified test pressure, and be held for a sufficient time for the preliminary inspection on all welds and connecting locations. If no leakage occurs, the pressure in testing may be continuously raised to 50% of the specified test pressure. If no any unusual phenomenon occurs, the pressure in testing may be raised step by step with a gradient of 10% of the specified test pressure up to the test pressure, and be held for a sufficient time. Then, the pressure is relieved to the design pressure and held a sufficient time for inspection. During inspection, the pressure shall be kept constant.

4.7.7.2 Acceptance criterion of pneumatic test

During the test, the pressure vessel with no unusual noise, no leakage during the test of soap liquid or other liquid, and no visible deformation can be identified as acceptable.

4.7.8 Pneumatic-hydrostatic combination test

(1) The pressure vessel which cannot be fully filled with liquid due to load-bearing or other reasons may subject to pneumatic-hydrostatic combination test with the routine of filling in liquid as the load-bearing capacity firstly and then filling in gas;

(2) The liquid and gas used in test shall meet the relevant requirements of (1) and (2) of Article 4.7.6.1, and the item (1) of Article 4.7.7.1;

(3) Requirements for the test temperature, pressure raising and pressure relieving, safety protection, and the acceptance criteria during pneumatic-hydrostatic combination test shall conform to the provisions of Article 4.7.7 in this Regulation.

4.8 Leak test

4.8.1 The conditions of leak test

(1) After the proof pressure test completed and accepted, leak test shall be conducted for the pressure vessel containing extremely or highly toxic medium, or permitting no slight leakage as

specified in designs;

(2) For the pressure vessel requiring pneumatic test as specified on design drawings, whether the leak test is required shall be prescribed on design drawings.

4.8.2 Types of leak test

Depending on the difference of test mediums, leak tests include gas tightness test, ammonia leak test, halogen leak test and helium leak test, etc. The option of test method shall satisfy the requirements of design drawings and quoted standards in this Regulation.

4.8.3 Gas tightness test

(1) The gases used in gas tightness test shall conform to the item (1) of Article 4.7.7.1 in this Regulation, and the test pressure is the design pressure of the pressure vessel;

(2) During gas tightness test, in general the safety accessories shall be completely mounted;

(3) After holding a sufficient time at the constant pressure, the pressure vessel with no leakage shall be identified as acceptable.

4.8.4 Ammonia leak test

According to the requirements of design drawings, ammonia leak test methods, such as ammonia-air method, ammonia-nitrogen method, 100% ammonia method can be used. The ammonia consistence, the test pressure, and the holding time for pressure are prescribed on design drawings.

4.8.5 Halogen leak test

In halogen leak test, requirements of vacuum level inside the vessel, the type of halogen gas, the test pressure, the holding time for pressure, and the test operation procedure are in accordance with the requirements of design drawings.

4.8.6 Helium leak test

In helium leak test, requirements of vacuum level inside the vessel, the consistence of helium, the test pressure, the holding time for pressure, and the test operation procedure are in accordance with the requirements of design drawings.

4.9 Additional requirements for pressure vessels of steel forgings, cast irons, stainless steels and non-ferrous metals

4.9.1 Forged-welded pressure vessels

(1) For steel forgings of pressure vessels, the designation, the chemical composition,

mechanical properties, process performance and examination requirements shall be in accordance with design drawings and the specifications of quoted standards in this Regulation;

(2) When the verification ring of a circumferential weld is required by design drawings, the material and dimensions of the ring, as well as the type, quantity, interception, testing methods, and the acceptance criterion of the circumferential weld test coupons shall be in accordance with design drawings;

(3) The cylindrical shell surface shall be machined, and the tolerances on geometric dimensions (abrupt rigid-or-valley, alignment offset, roundness, butt weld of unequal thicknesses, etc.) shall be in accordance with design drawings and quoted standards in this Regulation.

4.9.2 Cast pressure vessels

(1) The surface of cast iron pressure components must be free of cracks after fabrication. The casting defects such as shrinkage cavities, sand inclusions, blowholes and shrinkage porosities etc shall not exceed the requirements specified on design drawings. A liberal radius shall be provided at projecting edges and in reentrant corners to avoid abrupt changes on the surface contour and the wall thickness at junctures;

(2) A hydrostatic destructive test shall be conducted on the first trial product to verify the design rationality. If the test result is unacceptable, the batch of the product shall not be carried on. The test shall be properly planned with reliable safety measures.

4.9.3 Stainless steel and non-ferrous metal pressure vessels

(1) When fabricating pressure vessels or pressure components with stainless steels and non-ferrous metals, it shall have the specific workshop or specific equipments and the field to avoid mixing with ferrous metals or other products. The workshop or work field shall keep clean, dry and strictly controll dust;

(2) The processing/forming equipment and welding facility shall meet the requirements for the fabrication of stainless steels and nonferrous metals. Any mechanical damage and splash on the surface shall be strictly controlled;

(3) For Pressure vessels or pressure components with corrosion resistance and corrosion prevention requirements, the surface treatment must be conducted based on the requirements specified on design drawings, for instance, the austenitic stainless steel surface can be treated by acid pickling and passivation.

4.9.4 Non-ferrous metal pressure vessels

4.9.4.1 Groove processing

In general, the groove surface shall be processed mechanically, and other cutting methods that no damage to material properties and no effect on welding quality can also be used. If thermal cutting methods are adopted for the groove preparation, the oxidation layer and contamination layer shall be removed mechanically.

Requirements on the processed groove are as follows:

(1) For aluminum and titanium pressure vessels, cracks, laminations, inclusions of impurities and other defects affecting welding quality are not permitted at the groove surface;

(2) For copper and nickel pressure vessels, laminations, wrinkles, cracks, and lacerations are not permitted at the groove surface.

4.9.4.2 Aluminum pressure vessels

All supports of horizontal pressure vessels made of aluminum shall be fully contact with the shells.

4.9.4.3 Titanium pressure vessels

Titanium pressure vessels shall meet the following requirements:

(1) After welding, the surface color shall be inspected for all of the welded joints under as-welded condition, and the acceptance criteria shall be in accordance with quoted standards in this Regulation. The welded joints with unacceptable surface color shall be treated as specified in the quoted standards of this Regulation;

(2) The titanium head should be processed by hot forming. During the hot forming, necessary protection measures shall be taken to prevent the surface oxidation and contamination according to the requirements of quoted standards in this Regulation. After cold forming, the shape of the titanium head should be adjusted by heating.

4.9.4.4 Copper Heads

For copper heads, if the stress corrosion cracking may occur under the specified working environment, the annealing or stress relief annealing shall be performed in accordance with the requirements of design drawings and quoted standards in this Regulation.

4.9.4.5 Nickel Pressure vessels

The electrical furnace should be used for heating or heat treatment of nickel pressure vessels

and pressure components, the fuel gas furnace or the fuel oil furnace is also acceptable, but the coke or coal furnace is not allowed. When the gas furnace or the fuel oil furnace is used, the sulfur content in gas or oil shall be strictly controlled according to the requirements of quoted standards in this Regulation.

4.9.4.6 Other Requirements

Other fabrication and examination items of non-ferrous metal pressure vessels shall be in accordance with design drawings and the specifications of quoted standards in this Regulation.

4.10 Expanding

The flexible expanding methods or mechanical expanding methods may be used for the expanded joint of tube-to-tubesheet of heat exchangers. Before expanding, an expanding procedure specification shall be formulated, and the expanding operators shall make the joint expanding in conformity with the expanding procedure specification.

5 Installation, Alteration and Maintenance

5.1 Company of installation, alteration and maintenance

(1) The company engaged in installation, alteration and maintenance for pressure vessels shall be a corresponding manufacture license holder or a installation, alteration and maintenance license holder;

(2) The company engaged in installation, alteration and maintenance for pressure vessels shall establish a quality control system and implement effectively in accordance with the requirements of relevant safety technical regulations. The legal representative of the company shall be responsible for the quality of the installation, alteration and maintenance of pressure vessels;

(3) The company engaged in installation, alteration and maintenance for pressure vessels shall strictly implement involved rules of laws, safety technical regulations, and corresponding standards;

(4) The company engaged in installation, alteration and maintenance for pressure vessels shall provide the User with technical documentations, including drawings of installation, alteration and maintenance, and the conformity certificate of construction.

5.2 Notification of installation, alteration and maintenance

Prior to the installation, alteration and maintenance of pressure vessels, the company engaged in installation, alteration and maintenance shall submit a notification in writing to the Register authority for pressure vessel service.

5.3 Alteration and important repair

5.3.1 The definition and essential requirements of alteration and important repair

(1) The alteration of pressure vessels refers to the structural change of main pressure components, or the change of operating parameters, the change of containing medium or the change of service, etc The important repair of pressure vessels includes replacement, structural adjustment, removal and welding repair of main pressure components, and welding repair on a butt weld joint as specified in Article 3.14.1 of this Regulation;

(2) The scheme for alteration or important repair of pressure vessels shall be approved by the original Designer or a Designer holding relevant design license;

(3) After alteration or important repair, the structure and strength of pressure vessels shall be ensured to meet the requirements of safety service;

(4) The construction process of alteration or important repair on pressure vessels shall be supervisory inspected by the approved special equipment inspection and testing institute. The above mentioned pressure vessels can not be put into service unless they pass the required supervisory inspection.

5.3.2 Preparations before alteration and repair

The User of pressure vessels shall prepare and complete cleaning work following the requirements of *"Pressure Vessel Periodic Inspection Regulation"* prior to the alteration or repair personnel entering the pressure vessels. If the requirements are not met, it is prohibited to enter the pressure vessels.

5.3.3 Welding requirements of alteration and repair

(1) The construction plan for the removal and welding repair, replacement of the cylindrical segment and postweld heat treatment shall be formulated in accordance with the corresponding standards of design and fabrication, and this shall be approved by the technical chief of the company. The welding procedure qualification shall be conducted in accordance with the Article 4.2.1 of this Regulation;

(2) The welding can only be performed after the nondestructive examination is conducted to

ensure all flaws are completely removed. The nondestructive examination shall be performed again to ensure the welding quality;

(3) After welding repair on the base metal, it shall be grounded flush with the base metal;

(4) If the postweld heat treatment of stress relief is required, whether the stress relief heat treatment is necessary shall depend on the depth of repair defects for welding;

(5) If a main pressure component is replaced by a welding method or the repair welding depth is greater than 1/2 thickness of the pressure vessel, a proof pressure test shall be performed again.

5.4 Safety requirements for repair and under pressure leak sealing

Any repair with pressure in the vessel shall be prohibited. If the bolt-tightening under the certain temperature and pressure that it is required in some special production process, or if the under pressure leak sealing is required for an emergent leakage, the User shall provide the effective operating requirements and protective measures based on the design specification. All above shall be approved by the technical chief of the User.

The operating personnel shall take the professional training and hold the certificate for the operation of under pressure leak sealing. The operation shall be supervised on-site by the safety management department personnel of the User.

6 Service Management

6.1 Service register of the pressure vessel

Prior to putting into service of any special equipment or within 30 days after such putting into service, the User of the pressure vessel shall undergo the register for each pressure vessel to the Quality and Technical Supervision Department of municipalities directly under the Central Government or of cities divided into districts (it referred to as the Register authority) in accordance with the relevant provisions. The registration mark shall be presented in the appropriate location complying with the relevant provisions.

6.2 Responsibility of the User

The User shall be responsible for the safety management of pressure vessels. The technical personnels those who are ware the knowledge on pressure vessels and are familiar with the corresponding laws, administrative regulations, safety technical regulations, and standards shall

be assigned the duty of safety management of pressure vessels.

6.3 Safety management of pressure vessels

The safety management of the User shall include the followings:

(1) Implement this Regulation and corresponding safety technical regulations of pressure vessels;

(2) Establish and improve the safety management systems of pressure vessels, as well as the safety operating instructions;

(3) Register pressure vessels, and establish technical files for pressure vessels;

(4) Be responsible for the whole process managements of design, procurement, installation, service, alteration, repair and revoke, etc for pressure vessels;

(5) Organize the safety inspection of pressure vessels, conduct self-examination at least once per month, and make records;

(7) Implement the annual inspection and issue the inspection report;

(8) Make the annual periodic inspection plan, promot the arrangement and implementation of periodic inspection for special equipment, and control the hidden perils of accidents;

(9) Submit the annual statistical reports of the pressure vessel quantity and change situation in due year, the actual execution situation of the pressure vessel periodic inspection plan and the main problems happened with corresponding handling measures etc to the jurisdiction department and the local Quality and Technology Supervision Department;

(10) Report accidents of pressure vessels in accordance with the relevant provisions organize and participate in the rescue, assist and handle the investigation of pressure vessel accidents;

(11) Organize the education and training for operating personnels of pressure vessels;

(12) Establish the accident rescue countermeasure and organize the drilling.

6.4 Technical file of pressure vessels

The User of pressure vessels shall establish a technical file for each pressure vessel, and put the file control under administration. The technical file shall include the followings:

(1) Service register certificate of special equipment;

(2) Registration card of the pressure vessel;

(3) Design and fabrication documentation and information of the pressure vessel specified in

Article 4.1.4 of this Regulation;

(4) Reports of the annual inspection and the periodic inspection of the pressure vessel, as well as the technical documents and information of the relevant inspections;

(5) Technical information of repair and technical alternation schemes, drawings, material quality certificates, and construction quality certificate of the pressure vessel;

(6) Records of calibration, repair and replacement of safety accessories;

(7) Records and the corresponding handling reports of accidents.

6.5 Operation instruction of pressure vessels

The pressure vessel User shall clearly document the requirements for safety operation of pressure vessels in the process operation instructions and the operating post instructions. It shall at least include the following contents:

(1) Process operation parameters (include working pressure, maximum or minimum working temperature);

(2) Operating post instructions (including operating procedures to start-up/shutdown and attentions);

(3) Essential check items and locations on pressure vessels in operating, the probable unusual phenomena in operating and corresponding preventive measures, as well as handling and reporting procedures for emergency.

6.6 Operating personnel

Safety management personnels and operators of pressure vessels shall hold the appropriate operating personnel certificates of special equipment. The User shall conduct the periodical safety education and professional training to the operating personnels and make records. The User shall ensure operating personnels having the necessary knowledge on the safe operation of pressure vessels, operating skills, and updating knowledge timely. The User shall ensure that operating personnels can master operating instructions and accident emergency preplans, and work in accordance with the operating rules.

6.7 Routine maintenance

The User shall conduct the routine maintenance on pressure vessels and safety accessories, the safety protective devices, the measurement and control devices, and the affiliated apparatus and instruments. The unusual situations shall be treated and recorded immediately.

6.8 Annual inspection

The User shall perform the annual inspection of pressure vessels. The annual inspection shall at least include the inspections on the status of safety management, the main body of pressure vessels and operating performance, and the safety accessories of pressure vessels. The hidden perils of accidents for pressure vessels shall be resolved immediately.

The annual inspection should be performed by the professional personnels of the User, and also can be performed by the approved special equipment inspection and testing institute.

6.9 Handling of unusual situations

6.9.1 Emergency countermeasures and reports

When any of the following unusual case of pressure vessels occurs, the pressure vessel operator shall immediately take emergency action and report it immediately to the corresponding department in accordance with the specific procedure:

(1) Working pressure, medium temperature or wall temperature of the pressure vessel exceeds the specified value, and can not be effectively controlled by taking measures or adjustments;

(2) Damages affecting the safety of the pressure vessel such as cracks, blisters, deformations, leakage, and the lining layer failure etc are detected on the main pressure components;

(3) Control failure, damaged, or no longer are able to provide any protection of safety accessories;

(4) Safe operation cannot be warranted due to damage of nozzles or fasteners;

(5) Fire occurs that threaten the safe operation of pressure vessels;

(6) Over-filling occurs;

(7)Unusual liquid level in the pressure vessel occurs that cannot be effectively controlled even with the proper operating procedure;

(8) Serious vibration occurs between the pressure vessel and pipings that may impact the safe operation;

(9) Parts of the external wall of the vacuum insulation pressure vessel are seriously frozen, or the pressure and temperature of the medium are significantly increased;

(10) Any other unusual situations occur.

6.9.2 Treatment of hidden perils

The User shall inspect the pressure vessel immediately if a breakdown or an unusual situation occurs so as to eliminate any hidden perils. The User shall revoke immediately for the pressure vessel with serious hidden perils or being no worth of alteration and/or repair, and conduct cancellation of the register.

6.10 In service pressure vessels exceeded the design service life

For pressure vessels that have already reached the design service life, or have been in service for more than 20 years without any specification of design service life, if the User intends to use the pressure vessels continually, the User shall request the inspection by an approved special equipment inspection and testing institute (if necessary, safety evaluation shall be performed in accordance with Article 7.7 of this Regulation). Upon the approval of the responsible personnel of the User, the pressure vessels can be put into continuous service.

6.11 Purchase, out-of-service, ownership transfer, and re-installation of pressure vessels

The User shall not purchase any revoked pressure vessels. The out-of-service, ownership transfer, and re-installation of pressure vessels shall strictly conform to relevant regulations of inspection and service register.

6.12 Requirement for water quality

Pressure vessels used for generating steam with water as the medium shall have good water quality controls and monitoring systems, it is prohibited to be put into service if without reliable water treatment systems.

6.13 Requirements for connecting devices at filling and discharging

When filling and discharging operations between transportable and stationary pressure vessels are required, the connecting devices shall meet the following requirements:

(1) Pressure vessels shall be equipped with reliable connecting devices between the pipes or the flexible tubes of filling and discharging;

(2) Protective interlocking devices shall be installed to prevent disconnection of pipes or flexible tubes of filling and discharging;

(3) The materials for pipes or flexible tubes of filling and discharging shall be suitable with mediums and low temperature conditions, and the nominal pressure of the flexible tubes shall be not less than 2 times of the working pressure of the filling and discharging system, and the minimum bursting pressure shall be greater than 4 times of the nominal pressure;

(4) The pipes or the flexible tubes of filling and discharging shall be hydrostatic tested every 6 months, and the test pressure shall be 1.5 times of the nominal pressure. The test results shall be recorded and signed by the personnels who perform the test.

6.14 Emergency Rescue

In case of the possible accidents of the pressure vessel that can cause serious consequences or social impact, the User of the pressure vessel shall prepare the emergency rescue plan and establish the corresponding emergency rescue organization with suitable rescue equipments, and exercise trainings shall be performed appropriately.

7. Periodic inspection

7.1 Inspection application

The User shall submit the inspection application to the special equipment inspection institute for the periodic inspection one month prior to the expiration date of the pressure vessel. After receiving the periodic inspection application, the inspection institute shall conduct the inspection in time.

7.2 Inspection institute and Inspector

The inspection institute shall strictly carry out the periodic inspection in accordance with the approved inspection scope; the inspector shall hold the corresponding personnel certificate of special equipment inspection. The inspection institute shall be supervised by quality and technology supervision departments, and shall be responsible for the correctness of the conclusion regarding the periodic inspection of the pressure vessel.

7.3 Intervals of periodic inspection

The periodic inspection refers to the inspection and rating of the safety situation during the shutdown of pressure vessels. In general, the first periodic inspection shall be performed within the three years after pressure vessels being put into service. The next inspection interval can be determined by the inspection institute based on the safety situation rating as the following:

(1) For rating of the safety situation Class 1 or 2, the inspection interval generally shall be 6 years;

(2) For rating of the safety situation Class 3, the inspection interval generally shall be a period of 3—6 years;

(3) For rating of the safety situation Class 4, the pressure vessel shall be used under control. The inspection interval shall be determined by the inspection institute, and the time sum of control shall be no more than 3 years;

(4) For rating of the safety situation Class 5, all the defects shall be treated. Otherwise, the use of the pressure vessel shall be forbidden;

(5) Assessing the safety situation of the pressure vessel shall be in accordance with "*Periodic Inspection Regulations on Pressure Vessels"*. If all requirements are met, the inspection interval shall be adjusted shorter or longer appropriately;

(6) For the pressure vessel performed the risk-based inspection (RBI) technology, the inspection interval shall be determined in accordance with Article 7.8.3 of this Regulation.

7.4 The content of the periodic inspection

The inspection personnel shall prepare the inspection plan based on the service situation and possible failure modes of the pressure vessel. Periodic inspection methods mainly include the visual inspection, the thickness measurement and the surface nondestructive examination. If necessary, RT, UT, hardness test, metallographic examination, material property test, ET, strength verification or strain measure, proof pressure test, acoustic emission test, leak test etc. can also be used.

7.5 Proof pressure test in periodic inspection

The proof pressure test shall be conducted during the periodic inspection regarding the following cases:

(1) Main pressure components are alternated by welding;

(2) The welding repair depth of the main pressure component is over 1/2 of its original thickness;

(3)The operating conditions are changed above original design parameters of the pressure vessel, while the strength is still acceptable by strength check;

(4) Lining alteration is required (the proof pressure test shall be conducted prior to lining alteration);

(5) Pressure vessels are out-of-service for 2 years;

(6) Pressure vessels belong to the User or other enterprises are re-installed from the prior location;

(7) The User and/or the inspection institute considering the safety situations of pressure vessels are doubtful, and the proof pressure test is necessary.

7.6 Treatment of the special inspection situation

(1) For pressure vessels incapable of the periodic inspection as described on design drawings, the User shall give explanations in writing and report to the Register authority;

(2) For pressure vessels incapable of the periodic inspection as scheduled due to special reasons, the User shall submit the extension application to be approved by the chief responsible personnel. The inspection may be extended when the extension application approved by the original inspection institute and recorded by the Register authority. Alternatively, the User shall submit the application and follow the procedures in accordance with Article 7.8 of this Regulation;

(3) For pressure vessels incapable of periodic inspections or those incapable of periodic inspections as the schedule, the appropriate safety control countermeasures shall be taken.

7.7 Fitness-for-purpose

For pressure vessels with rating of the safety situation Class 4 and/or the control period close to the due date, or those in which serious defects found on the vessels during periodic inspections that may eventually lead to pressure vessels out-of-service, all defects shall be treated. Methods for the treatment of defects include eliminating defects by repairing or subjecting to fitness-for-purpose. The fitness-for-purpose shall meet the following:

(1) The inspection institute that undertakes fitness-for-purpose of the pressure vessel shall be approved by AQSIQ;

(2) The User shall submit an application in writing for fitness-for-purpose to the approved inspection institute. Meanwhile, the User shall notify in wiring to the Register authority regarding the basic situation of the pressure vessel;

(3) The fitness-for-purpose of the pressure vessel shall be performed in accordance with GB/T 19624 *"safety assessment for in-service pressure vessels containing defects"*. The inspection institute undertaken the fitness-for-purpose shall provide evaluation conclusion and clarify potential effects upon the safety operating based on the property, the origin and the prediction of existing defects;

(4)The report of the fitness-for-purpose of the pressure vessel shall be issued by the

experienced person. The report shall be approved by the legal representative of inspection institute or the technical chief of the institute. The inspection institute undertaken the fitness-for-purpose shall be responsible for the correctness of the evaluation conclusion;

(5) Based on the fitness-for-purpose conclusion and the inspection results, the inspection institute shall determine the rating of safety situation, allowable operation parameters and the next inspection date, and issue the inspection report;

(6) The User shall report the fitness-for-purpose conclusion to the Register authority. The User shall follow operation parameters of the pressure vessel strictly in accordance with the requirement of the inspection report, and reinforce the annual inspection.

7.8. Risk-based inspection (RBI)

7.8.1 Application condition

The User shall submit the technical application for the risk-based inspection (hereinafter referred to as RBI) to AQSIQ when the User of the petrol-chemical plant meets the following:

(1) Having a well-established management system and a high management level;

(2) Having a well-established emergency preplan to deal with different emergency situations and exercise trainings regularly;

(3) The equipments including pressure vessels and pressure pipings are operated well, and be inspected and maintained in accordance with relevant provisions;

(4) Records regarding production facilities and key equipments are complete;

(5) Operating processes are stable;

(6) Digital distribution control systems are integrated into production facilities with reliable safety protective interlocking systems.

7.8.2 The implementation of RBI

(1) The inspection institute who undertakes RBI shall be approved by AQSIQ;

(2) Once the request of RBI is approved by AQSIQ, the User shall submit an application to an approved RBI inspection institute, and notify in writing to the Register authority;

(3) The RBI inspection institute shall evaluate risk levels of equipments and pressure vessels based on the status of equipments, failure modes, failure consequences and management conditions;

(4) Based on risk analysis results, the RBI inspection institute shall formulate a detailed

inspection proposal including the inspection timing, contents and methods on the premise that the risk level of the pressure vessel is acceptable;

(5) The User shall prepare an inspection plan based on the inspection proposal, and the inspection shall be implemented by the inspection institute;

(6) For the pressure vessel with risk level above the acceptable level during operation, the online inspection or other methods shall be adopted to minimize the risk;

(7) The User of pressure vessels based on RBI shall give the notification of RBI conclusions to the Register authority, implement various measures to ensure the safety operation of pressure vessels, and undertake the responsibility of the safety subject.

7.8.3 Determine the inspection interval

The inspection interval of pressure vessels based on RBI can be determined by the following:

(1) The rating of safety situation levels and the inspection interval of pressure vessels can be determined in accordance with *"Periodic Inspection Regulations of Pressure Vessels"*, and the inspection interval can be shorter or longer based on the risk level of pressure vessels, but it shall not be longer than 9 years;

(2) Based on the remaining service life of pressure vessels, the longest inspection interval shall not be longer than half of the remaining service life, and shall not be longer than 9 years.

8. Safety Accessory

8.1 General requirement

(1) The manufacturer of safety valves, rupture disk devices shall hold the appropriate manufacturing license of special equipment;

(2) For safety accessories requiring type (prototype) tests, such as safety valves, rupture disk devices and emergency shut-off devices etc, type(prototype) tests shall be conducted by the approved type test institute of AQSIQ, and proof documents of type tests shall be obtained;

(3) The design and fabrication of safety accessories shall conform to provisions of corresponding safety technical regulations;

(4) The safety accessory shall be delivered together with the quality certificate, and a metallic nameplate shall be tightly mounted on the product;

(5) The periodic inspection of safety accessories shall be carried out regularly, and the periodic inspection shall conform to provisions of *"Periodic Inspection Regulations on Pressure Vessels"* and corresponding safety technical regulations.

8.2 Installation requirements of safety accessories

(1) Pressure vessels within the jurisdiction scope of this Regulation shall be equipped with safety relief devices (safety valves or rupture disk devices) based on the design requirement. When the external pressure source can be reliably controlled, the safety relief device shall not be mounted directly on the pressure vessel;

(2) When the combination of rupture disk device and safety valve is used, it shall conform to corresponding specifications of GB 150. Rupture disks in series of the combination structure shall not be allowed to break into fragments during bursting;

(3)For pressure vessels containing explosive or extremely, highly or moderately toxic medium, a relief tube shall be mounted at the outlet of the safety valve or the rupture disk. The discharged substance shall be guided to a safe place and properly disposed. It is prohibited to directly the discharge into air atmosphere;

(4) When the working pressure of the pressure vessel is less than the source pressure, a pressure reducing valve shall be mounded on the piping connected to the inlet of the pressure vessel. If the pressure reducing valve may not operate reliably due to the medium, a pressure regulating valve may be used instead of the pressure reducing valve. Then, the safety valve and the pressure gage shall be mounted at the lower pressure side of the pressure reducing valve or the regulating valve.

8.3 safety valves and rupture disks

8.3.1 The discharge capacity of safety valves and rupture disks

The discharge capacity of the safety valve and the rupture disk shall be equal to or greater than the safety relief capacity of the pressure vessel. The calculations for the discharge capacity and the safety relief capacity are based on the relevant specification of GB 150. For the pressure vessel containing the mixed gas/liquid medium under saturated or overheated condition, the relief area of the outlet for the rupture disk device shall be calculated in design to prevent from explosion.

8.3.2 The set pressure of safety valves

In general, the set pressure of safety valves shall not be greater than the design pressure of the pressure vessel. The maximum allowable working pressure may be used as the set pressure of safety valves when the value of the maximum allowable working pressure is indicated on design drawings or on the nameplate.

8.3.3 The bursting pressure of rupture disks

If the pressure vessel equipped with rupture disk devices, the design bursting pressure of the rupture disks shall not be greater than the design pressure of the pressure vessel, and the minimum design bursting pressure of the rupture disk shall not be less than the working pressure of the pressure vessel. If the maximum allowable working pressure is indicated on design drawings or the nameplate, the design bursting pressure of the rupture disk shall not be greater than the maximum allowable working pressure of the pressure vessel.

8.3.4 The action system of safety valves

Deadweight safety valves shall have the anti-deviation device to prevent the weight from freely shifting and guide frame to limit the leverage deviation; spring-loaded safety valves shall have the seal device to prevent the adjusting screw from casual pinch; and direct-loaded safety valves shall have the protection device to prevent the weight from moving away.

8.3.5 Installation requirements for safety valves

(1) Safety valves shall be plumb mounted at the gas phase space over the liquid level of the pressure vessel, or be mounted on the pipe that connected to the gas phase space of the pressure vessel;

(2) The cross-sectional area of the connecting pipe and the fitting between the pressure vessel and the safety valve shall be not less than the inlet part of the safety valve. The connecting pipe shall be as short and straight as possible;

(3) When two or more safety valves are mounted on one inlet pipe of the pressure vessel, the cross-sectional area of the inlet pipe shall be at least equal to the sum of the cross-sectional areas of inlets of those safety valves;

(4) In general, the globe valve should not be mounted between the safety valve and the pressure vessel. For the purpose of the on-line check of the safety valve, a rupture disk device may be mounded between the safety valve and the pressure vessel. In the case of the pressure vessel containing extremely/ highly or moderately toxic medium, explosive medium, corrosive or

sticky medium or valuable medium, a globe valve may be mounted between the safety valve (rupture disk device) and the pressure vessel in order to facilitate cleaning and replacement of the safety valve with the approval of the User's safety chief and the reliable protection measures. The globe valve shall be kept at a full-open position (by lead seal or lock device) under the normal operating condition of the pressure vessel. The structure and the nominal diameter of the globe valve shall not block the relief of the safety valve;

(5) A new safety valve shall be calibrated prior to installation.

8.3.6 The calibration institute of safety valves

The calibration institute of safety valves shall possess qualified calibration technicians, calibration equipment/apparatus and workplace, as well as the corresponding procedure and system. The calibration technician shall hold the personnel certificate of the safety valve maintenance. After the calibration, the calibration institute shall present a calibration report and seal the calibrated safety valve.

8.4 Pressure gage

8.4.1 The selection of the pressure gages

(1) Pressure gages shall be compatible with the medium contained in the pressure vessel;

(2) For pressure vessels with design pressure less than 1.6MPa, the precision of pressure gages shall not be lower than Class 2.5. For pressure vessels with the design pressure equal to or greater than 1.6MPa, the precision of pressure gages shall be not lower than Class 1.6;

(3) The maximum scale on the pressure gage shall be 1.5-3.0 times of the design pressure and the dial diameter shall not be less than 100mm.

8.4.2 The calibration for pressure gages

The calibration and maintenance for pressure gages shall conform to corresponding provisions regulated by the Metrology Authority of China. Pressure gages shall be calibrated prior to installation. A red line shall be marked on the dial to indicate the working pressure, and the next calibrating date shall be indicated. A lead seal shall be put on the pressure gage after calibrating.

8.4.3 Installation requirements for pressure gages

(1) Pressure gages shall be located at the position for easy observation and cleaning. Any adverse effects such as direct radiation, freezing or vibration shall be avoided；

(2) A three-way cock or a needle valve (with the on-off label and the lock device) shall be mounted between the pressure gage and the pressure vessel, and any fitting or nozzle used for other service shall not be connected between the pressure gage and the pressure vessel;

(3) For pressure gages used for steam as the medium, a bent pipe for collecting condensed water shall be mounted between the pressure gage and the pressure vessel;

(4) For pressure gages used for the corrosive or highly sticky medium as the medium, a buffer device for isolating the medium shall be mounted between the pressure gage and the pressure vessel.

8.5 Liquid level gages

8.5.1 General requirements of liquid level gages

Liquid level gages used for pressure vessel shall conform to the following:

(1) The selection of liquid level gages of the pressure vessel is based on the medium contained, the design pressure and temperature of the pressure vessel;

(2) Prior to installation and usage, the liquid level gage used for the pressure vessel with the design pressure less than 10MPa shall be hydrostatically tested with a pressure of 1.5 times of the nominal pressure of the liquid level gage. For the pressure vessel with the design pressure equal to or greater than 10MPa, the liquid level gage shall be tested hydrostatically with a pressure of 1.25 times of the nominal pressure of the liquid level gage;

(3) For the pressure vessel containing low-temperature (less than 0℃) medium, a frost-proof liquid level gage shall be used;

(4) For the liquid level gage used outdoor in the cold climate region, a jacket or a thermal insulation type liquid level gage shall be used;

(5) For the pressure vessel containing the explosively or extremely, highly toxic liquefied gas, the liquid level gage shall be equipped with the protection device against leakage;

(6) When a stable indication of the liquid level is required, the float-type (buoy-type) liquid level gage shall not be used.

8.5.2 Installation of liquid level gages

A Liquid level gage shall be located at the position for easy observation. Otherwise other auxiliary devices shall be provided. For the large scale pressure vessel, a central-control system with an alert/alarm device shall be provided. The highest and lowest safe liquid level positions on

liquid level gage shall be marked clearly.

8.6 Test apparatus for wall temperature

For pressure vessels requiring the wall temperature control, a thermometry apparatus (or thermometer) shall be equipped. The thermometry apparatus shall be calibrated periodically.

9. Supplement

9.1 Interpretation authorization

AQSIQ has the authority to provide official interpretations of this Regulation.

9.2 Enforcement date

This Regulation is enforced on December 1st, 2009. Accordingly, provisions about stationary pressure vessel in *"Supervision Regulation on Safety Technology for Pressure Vessel"* (issued by SBQTS/BPA [1999] No. 154) published by State Bureau of Quality and Technical Supervision June 25th, 1999 is repealed.

ANNEX A

CLASSIFICATIONS FOR CATEGORIES, PRESSURE CLASSES, AND SORTS OF PRESSURE VESSELS

A1 Classification for categories of pressure vessels

A1.1 Medium grouping

Mediums of pressure vessels are classified into two groups, including gases, liquefied gases, and liquids with the maximum working temperature equal to or greater than the standard boiling point, as the following:

(1) The medium group 1: chemicals with toxicity of extremely hazard or highly hazard, explosive mediums, liquefied gases;

(2) The medium group 2: mediums except for those in the first group.

A1.2 Hazards of the medium

Hazards of the medium refer to the severity of hazards resulted from mass contact of human body with medium due to accidents, explosions, or occupational chronic harmfulness resulted from frequent leak of medium during production. It is indicated by the toxicity degree and the explosiveness of the medium.

A1.2.1 Toxicity level

Regarding hazardous factors of the acute toxicity, the maximum permissible concentration and the occupational chronic hazard comprehensively, the maximum permissible concentration of the extreme toxic medium is less than 0.1mg/m^3; the maximum permissible concentration of the highly toxic is 0.1mg/m^3~1.0mg/m^3; the maximum permissible concentration of the moderate toxic is 1.0mg/m^3~10.0mg/m^3; the maximum permissible concentration of the light toxic is equal to or greater than 10.0mg/m^3.

A1.2.2 Explosive mediums

Explosive mediums refer to the explosive mixture when the vapor and the mist of gases or liquids form with the air, which the lower explosion limit is less than 10% or the difference between upper and lower explosion limits is equal to or greater than 20%.

A1.2.3 Determination of the hazardous degree of the toxic medium and explosive medium (refer to Annex 1, 3(1))

The medium group shall be determined according to HG 20660—2000 *"Classification for Toxicity and Explosiveness of Chemical Medium in Pressure Vessels".* When not provided

in HG 20660, the medium group should be determined by the Designer of the pressure vessel based on GB 5044—85 *"Classification for Harmfulness of Occupational Contact with Toxic Medium"*.

A1.3 Classification for Categories of Pressure Vessels

A1.3.1 Basic classification

Based on characteristics of the medium, the classification for categories of pressure vessels is determined by the design pressure *p* (Unit: MPa) and the volume *V* (Unit: L), and the categorization figures for different medium groups are as the following:

(1) The medium group1, the classification for categories of pressure vessels, see Fig.A-1;

(2) The medium group2, the classification for categories of pressure vessels, see Fig.A-2.

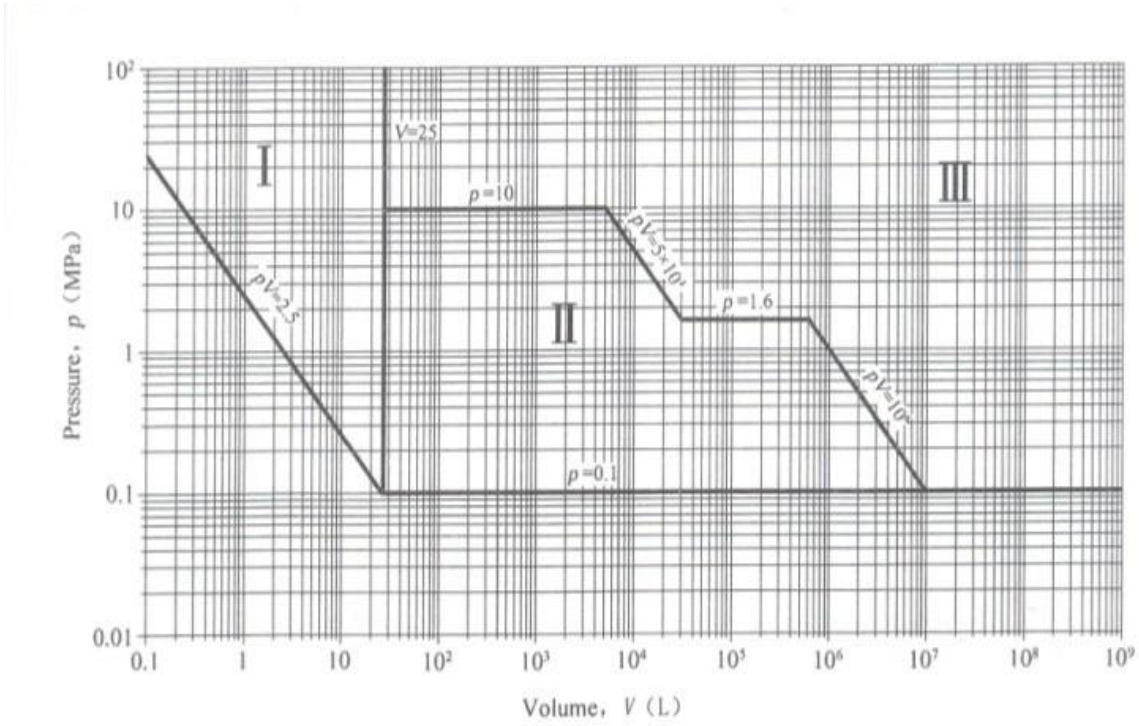


Fig.A-1 Classification for categories of pressure vessels - the medium group1

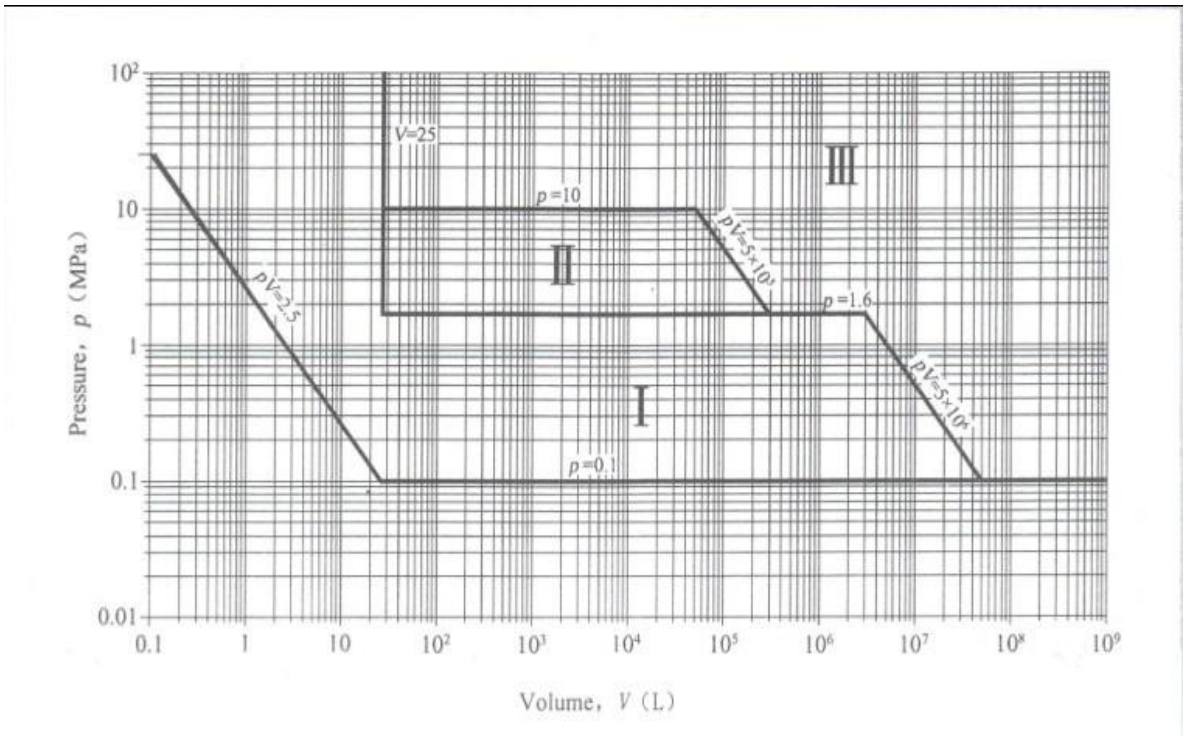


Fig.A-2 Classification for categories of pressure vessels - the medium group2

A1.3.2 Classification for categories of pressure vessels with multiple chambers

For pressure vessels with multiple chambers (such as tube-side and shell-side of heat exchangers, and jacket pressure vessels etc), the vessel category and corresponding service management are based on the relatively higher category among these pressure chambers. But the technical requirements for design and fabrication of each pressure chamber shall be determined in accordance with the corresponding category of that pressure chamber respectively. When the category of each pressure chamber is classified, the design pressure shall be taken as the corresponding design pressure of that chamber and volume taken as the geometric volume of that chamber.

A1.3.3 Classification for categories of pressure vessels with multiple mediums in the same chamber

When multiple mediums are contained in the same pressure chamber, the vessel category is based on the highest category among these mediums.

A1.3.4 Classification for categories of pressure vessels with extremely small amount of medium

When the quantity of a hazardous substance is extremely low in the medium, considering the hazard and quantity comprehensively, the vessel category shall be determined based on the medium category provided by the Designer of the pressure vessel.

A1.3.5 Classification for categories under special conditions

(1) When the (p,V) is located at the category line in Fig.A-1 or Fig.A-2, the vessel category shall be determined based on the relatively higher category;

(2) Pressure vessels in Article 1.4 of this Regulation are all classified to be category I.

A2 Classification of pressure classes

Based on the design pressure (p), the classification for pressure classes is specified as following four classes: low pressure, medium pressure, high pressure and ultrahigh pressure:

(1) Low pressure (symbol L), $0.1\text{MPa} \leq p < 1.6\text{MPa}$;

(2) Medium pressure (symbol M), $1.6\text{MPa} \leq p < 10.0\text{MPa}$;

(3) High pressure (symbol H), $10\text{MPa} \leq p < 100\text{MPa}$;

(4) Ultrahigh pressure (symbol U), $p \geq 100\text{MPa}$.

A3 Classification of the pressure vessel sorts

Based on the function in the production process, the classification for the pressure vessel sorts is divided to reaction vessels, heat-exchange vessels, separation vessels and storage vessels. It specified as following:

(1) Reactor vessels (symbol R): pressure vessels mainly used for physical or/and chemical reactions of mediums, such as various types of reactors, reaction kettles, polymerization kettles, synthesis converters, transformation furnaces, gas generators etc;

(2) Heat-exchanger vessels (symbol E): pressure vessels mainly used for heat exchange of mediums, such as various types of heat exchangers, coolers, condensers, evaporators, etc;

(3) Separation vessels (symbol S): pressure vessels mainly used for fluid pressure balance/damping of mediums, and gas cleaning/separating, such as various types of separators, filters, oil collectors, washers, absorption towers, cuprammonium washing towers, drying towers, stripping towers, steam distributors and deaerators etc;

(4) Storage vessels (symbol C, for spherical tanks, symbol B): pressure vessels mainly used for storing and containing substance of gases, liquids, or liquefied gases etc, such as various types of storage tanks, buffer tanks, sterilizing pots, dyeing machines, dryers, steaming pots, etc.

When two or more functions exist in the same pressure vessel, the sort classification shall be based on the main function in the process.

ANNEX B

PRODUCT COMFORMITY CERTIFICATE OF PRESSRUE VESSELS

Serial Number:

Name of Manufacturer			
Code of Organization		Manufacture License Number	
Product Name		Manufacture Licensing Level	
Product Number		Equipment Code	
Drawing Number		Category of Pressure Vessels	
Designer			
Code of Organization		Designer License Number	
Design Date		Manufacture Date	

This pressure vessel conforms to the requirements of "*Supervision Regulation on Safety Technology for Stationary Pressure Vessel"*, the design drawings, relevant technical standards, and the purchase contract via quality inspection in fabrication process.

Responsible Inspection Engineer (Signature / Stamp): Date:

Quality Control Engineer(Signature / Stamp): Date:

Seal for product quality inspection

Year Month Day

Note: This certificate includes Product Data Sheet of the pressure vessel that is attached, the manufacturer shall input its information into equipment database of special equipment, following the requirements of special equipment informationization.

ANNEX b PRODUCT DATA SHEET OF PRESSURE VESSELS

Serial Number:

<table>
<tr><td colspan="2">Equipment Type</td><td colspan="3">Stationary pressure vessel</td><td colspan="2">Pressure Vessel Sort</td><td colspan="3"></td></tr>
<tr><td colspan="2">Product Name</td><td colspan="3"></td><td colspan="2">Product Serial Number</td><td colspan="3"></td></tr>
<tr><td colspan="2">Equipment Code</td><td colspan="3"></td><td colspan="2">Pressure Vessel Category</td><td colspan="3"></td></tr>
<tr><td colspan="2">Product Standard</td><td colspan="3"></td><td colspan="2">Design Service Life</td><td colspan="3"></td></tr>
<tr><td rowspan="8">Main Parameters</td><td colspan="2">Vessel Volume</td><td>m^3</td><td colspan="2">Vessel Inner Diameter</td><td>mm</td><td colspan="2">Vessel Height(Length)</td><td>mm</td></tr>
<tr><td rowspan="4">Materials</td><td>Shell</td><td></td><td rowspan="4">Thickness</td><td>Shell</td><td>mm</td><td colspan="2">Shell Weight</td><td>kg</td></tr>
<tr><td>Head</td><td></td><td>Head</td><td>mm</td><td colspan="2">Internals Weight</td><td>kg</td></tr>
<tr><td>Inner Lining</td><td></td><td>Inner Lining</td><td>mm</td><td colspan="2">Filling Weight</td><td>kg</td></tr>
<tr><td>Jacket</td><td></td><td>Jacket</td><td>mm</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">Design Pressure</td><td>Shell-side</td><td>MPa</td><td rowspan="3">Design Temperature</td><td>Shell-side</td><td>℃</td><td rowspan="3">Maximum Allowable Working Pressure</td><td>Shell-side</td><td></td></tr>
<tr><td>Tube-side</td><td>MPa</td><td>Tube-side</td><td>℃</td><td>Tube-side</td><td></td></tr>
<tr><td>Jacket</td><td>MPa</td><td>Jacket</td><td>℃</td><td>Jacket</td><td></td></tr>
<tr><td colspan="2">Shell-side Medium</td><td></td><td colspan="2">Tube-side Medium</td><td></td><td colspan="2">Jacket Medium</td><td></td></tr>
<tr><td rowspan="2">Structure Types</td><td colspan="2">Structure Type of Main Body</td><td colspan="3"></td><td colspan="2">Installation Type</td><td colspan="3"></td></tr>
<tr><td colspan="2">Support Type</td><td colspan="3"></td><td colspan="2">Thermal Isolation / Insulation Methods</td><td colspan="3">(Fill in methods, or mark “—” if not applicable)</td></tr>
<tr><td rowspan="3">Examination and Test</td><td colspan="2">Nondestructive Examination Methods</td><td colspan="3"></td><td colspan="2">Nondestructive Examination Degree</td><td colspan="3">%</td></tr>
<tr><td colspan="2">Types of Proof Pressure Test</td><td colspan="3"></td><td colspan="2">Test Pressure of Proof Pressure Test</td><td colspan="3">MPa</td></tr>
<tr><td colspan="2">Types of Leak Test</td><td colspan="3"></td><td colspan="2">Pressure of Leak Test</td><td colspan="3">MPa</td></tr>
<tr><td colspan="3">Type of Heat Treatment</td><td colspan="3"></td><td colspan="2">Heat Treatment Temperature</td><td colspan="3">℃</td></tr>
<tr><td colspan="10">Safety Accessories and relevant devices</td></tr>
<tr><td colspan="3">Name</td><td colspan="2">Model</td><td colspan="2">Specification</td><td>Quantity</td><td colspan="2">Manufacturer</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td>Manufacturing Supervisory</td><td colspan="2">Supervisory Inspection Institute</td><td colspan="7"></td></tr>
</table>

Inspection	Organization Code		Approved Certificate Number	

ANNEX C

PRODUCT NAMEPLATE OF PRESSURE VESSELS

(1) Product nameplate of pressure vessels

Supervisory Inspection Marking

Product Name				•	
Product Serial Number		Pressure Vessel Category		Manufacture Date	Year, Month, Day
Design Pressure	MPa	Test Pressure of Proof Pressure Test	MPa	Maximum Allowable Working Pressure	MPa
Design Temperature	℃	Vessel Net Weight	kg	Main Body Materials	
Volume	m^3	Working Medium		Product Standard	
Manufacture Licensing Level		Manufacture License Number			
Manufacturer Name					
Equipment Code		Service Registration Number			

The rubbing or copy of the nameplate shall be put into product quality certification documents of pressure vessels.

(2) Product Nameplate of Heat Exchangers

Supervisory Inspection Marking

Product Name				●	
			Tube-side (Jacket)	Shell-side（Shell）	
Product Serial Number		Design Pressure	MPa	MPa	
Pressure Vessel Category		Test Pressure of proof Pressure Test	MPa	MPa	
Manufacture Date	Year, month, day	Maximum Allowable Working Pressure	MPa	MPa	
Vessel Net Weight	kg	Design Temperature	℃	℃	
Heat Transfer Area	m^2	Working Medium			
Distance between Two Baffles	mm	Main Body Materials			
Product Standard		Manufacture Licensing Level		Manufacture License Number	
Manufacturer Name					
Equipment Code		Service Registration Number			

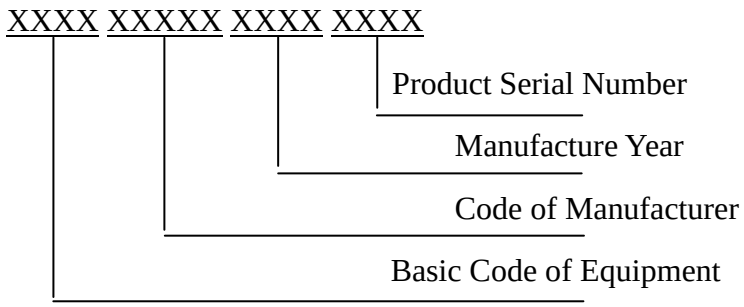
The rubbing or copy of the nameplate shall be put into Product Quality Certification Documents of pressure vessels.

ANNEX D

CODE NUMBERING METHODS OF SPECIAL EQUIPMENTS

D1 Basic numbering methods

The equipment code is the identification of the equipment, which must be unique, and consists of the basic code of the equipment, the code of the manufacturer, the fabrication year, and the product serial number, between which there are no spaces.



D2 Meaning of the code

D2.1 Basic code of the equipment

It is compiled according to the equipment code (4 Arabic numerals) of the variety listed in the *"Special Equipment Catalogue"*. For example, for high pressure vessels, the code is '2120'.

D2.2 Code of Manufacturer

The code of the manufacturer is consisted of the code of the administrative region (2 Arabic numerals) where the approval authority of manufacture license is located and the manufacturer serial number (3 Arabic numerals) included in the manufacture license number of the manufacturer. For instance, for a manufacturer of pressure vessels located in Heilongjiang Province, if it is reviewed and approved by AQSIQ, its manufacturer license number is 'TS2210890 – 2008', in which the code of the administrative region for AQSIQ is indicated by 10, the serial number of the license is 890, and then the code of the manufacturer is '10890'. If it is reviewed and approved by the Quality & Technology Supervision Bureau of Heilongjiang Province, then its manufacture license number code is 'TS2223010 – 2008', in which the code of the administrative region for Heilongjiang Province is indicated by 23, the serial number of the license is 10, and then the code of the manufacturer is '23010'.

D2.3 Manufacture year

The year when the product is manufactured (4 Arabic numerals). For example, for a product fabricated in 2008, the manufacture year is ‘2008’.

D2.4 Product serial number

The product serial number is numbered by the manufacturer itself (4 Arabic numerals). For example, for a type of the pressure vessel fabricated in 2008, if the fabrication serial number is 89, then it is numbered as ‘0089’.

If the product serial number exceeds 9999, then it can be replaced by phonetic alphabet. For example, if the fabrication serial number for a certain variety pressure vessel is 10000 or 11000, then the product serial number is A000 or B000, and the rest can be deduced by analogy.