NB

INDUSTRY STANDARD OF THE

PEOPLE'S REPUBLIC OF CHINA

ICS 27.060.30

J 75

NB/T 47006-2009

Replacing JB/T 7261-1994

Aluminum Plate-fin Heat Exchanger

铝制板翅式热交换器

Issued on: March December 01, 2009 **Implemented on: May 01, 2010**

Issued by: National Energy Board of the People's Republic of China

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Aluminum plate-fin heat exchanger

1 Scope

This standard specifies the requirements of design, manufacture, inspection acceptance, installations, application and maintenance of Aluminum plate-fin heat exchanger (hereinafter referred to as heat exchange).

1.1 This standard is applicable to the heat exchanger with design pressure no greater than 8.0MPa. For the heat exchanger with design pressure greater than 8.0MPa, it may be designed and manufactured with reference to this standard when the buyer is agreed upon.

1.2 The design temperature range suitable to this standard is -269°C~200°C.

1.3 This standard is applicable to the heat exchangers applied in the situation of air separation and liquification equipment (ASU), natural gas processing (NGP) and liquification (LNG), petrochemical engineering and mechanical power devices.

1.4 The pressure parts of heat exchanger which couldn't be determined by this standard, through the assessment and ratification of the National Technical Committee on Boilers and Pressure Vessels of Standardization Administration of China, may be designed by adopting the following methods:

a) The stress analysis (except the unit qualified for analysis design) including finite element method;

b) Replication experimental analysis (such as experimental stress analysis and replication hydraulic test);

c) The comparable structure which has been put into service shall be adopted to carry out the comparison empirical design.

2 Normative References

The following documents are indispensable to the application of this standard. For dated reference, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

GB 150 Steel Pressure Vessels

GB/T 228 Metallic Materials - Tensile Testing at Ambient Temperature (GB/T 228-2002, ISO 6892: 1998(E), EQV)

GB/T 229 Metallic materials - Charpy Pendulum Impact Test Method (GB/T 229-2007, ISO 148-1: 2006, MOD)

GB/T 232 Metallic Materials - Bend Test (GB/T 232-1999, ISO 7438: 1985, EQV)

GB/T 1804 General tolerances - Tolerances for Linear and Angular Dimensions without Individual Tolerance Indications (GB/T 1804-2000, ISO 2768-1: 1989, EQV)

GB/T 2624.1-2006 Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-section Conduits Running Full - Part 1: General Principles and Requirements (GB/T 2624.1-2006, ISO 5167-1: 2003, IDT)

GB/T 2624.2-2006 Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-section Conduits Running Full - Part 2: Orifice Plates(GB/T 2624.2-2006, ISO 5167-2: 2003, IDT)

GB/T 2624.3-2006 Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-section Conduits Running Full -Part 3: Nozzles and Venturi nozzles (GB/T 2624.3-2006, ISO 5167-3: 2003, IDT)

GB/T 2624.4-2006 Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-section Conduits Running Full - Part 4: Venturi Tubes (GB/T 2624.4-2006, ISO 5167-4: 2003, IDT)

GB/T 3190 Wrought Aluminum and Aluminum Alloys - Chemical Composition Limits (GB/T 3190-2008, ISO 209: 2007(E), MOD)

GB/T 3191-1998 Extrusion Rods and Bars of Aluminum and Aluminum Alloy

GB/T 3195-2008 Aluminum and Aluminum Alloys Drawn Round Wire

Aluminum and Aluminum-alloy Foil

GB/T 3246.1 Wrought Aluminum and Aluminum Alloys Products Inspection Method for Structure

GB/T 3246.2 Wrought Aluminum and Aluminum Alloys Products Inspection Method for Macrostructure

GB/T 3880.1-2006 Wrought Aluminum and Aluminum Alloy Plates, Sheets and Strips for General Engineering - Part 1: Technical Conditions of Delivery

GB/T 3880.2-2006 Wrought Aluminum and Aluminum Alloy Plates, Sheets and Strips for General Engineering - Part 2: Mechanical Properties

GB/T 3880.3-2006 Wrought Aluminum and Aluminum Alloy Plates, Sheets and Strips for General Engineering - Part 3: Tolerances on Forms and Dimensions

GB/T 4436 Wrought Aluminum and Aluminum Alloy Tubes - Dimensions and Deviations

GB/T 4437.1-2006 Aluminum and Aluminum Alloy Extruded Tubes - Part 1: Seamless Tubes

GB/T 6892-2006 Wrought Aluminum and Aluminum Alloys Extruded Profiles for General Engineering

GB/T 6893-2000 Aluminum and Aluminum Alloy Cold Drawn (rolled) Seamless Tubes

GB/T 8063-1994 Designation of Cast Nonferrous Metals and Their Alloys (GB/T 8063-1994, ISO 2092, NEQ)

GB/T 9438-1999 Aluminum Alloy Casting (GB/T 9438-1999, ASTM B26/B26M:1992, NEQ)

GB/T 10858-2008 Aluminum and Aluminum Alloy Wires and Rods

GB/T 13384 General Specifications for Packing of Mechanical and Electrical Product

GB/T 16474 Wrought Aluminum and Aluminum Alloy-Designation System (GB/T 16474-1996, ANSI H35.1:1993, EQV)

GB/T 16475 Temper Designation System for Wrought Aluminum and Aluminum Alloy (GB/T 16475-2008, ISO 2107:2007, MOD)

JB/T 4730.2-2005 Nondestructive Testing of Pressure Equipment - Part 2: Radiographic Testing

JB/T 4730.3-2005 Nondestructive Testing of Pressure Equipment - Part 3: Ultrasonic Testing

JB/T 4730.5-2005 Nondestructive Testing of Pressure Equipment - Part 5: Penetrant Testing

JB/T 4734 Aluminum Welded Vessels

3.3.3 Heat transfer fin

It is the primary part of heat exchanger and the heat transfer process is mainly finished through the heat conduction of heat transfer fin as well as the convection heat transfer between the heat transfer fin and fluid.

3.3.4 Distributor fin

It shoulders mail the steering function for the fluid inlet and outlet, and it is generally multi-orifice heat transfer fin.

3.3.5 Side bar

It is the primary part of heat exchanger, which are dispersed over the margins of heat exchanger and acts to seal and support each layer of passage.

3.3.6 Parting sheet

It is the metal sheet between two layers of heat transfer fins, also called composite sheet; it covers a layer of brazing alloy on the surface of parent metal and when it is brazed, the alloy is melted and the heat transfer fin, side bar and sheet are welded together.

3.3.7 Cap sheet

It is the parting sheet located at the outermost side of the heat exchanger block (core), also called cover plate.

3.3.8 Dummy layer

It is the layer which is set on the top and bottom of the block (core) to connect with the ambient atmosphere for heat exchange resistance according to the requirements of strength, heat isolation and manufacture process. (And it is called the process layer).

3.3.9 Dead area

It refers to the area where the heat transfer fin or distributor fins are connected or unconnected without media flowing.

3.3.10 Layer arrangement

The layer arrangement manners may be classified into single banking, double banking and single and multiple banking.

3.4.1.6 When the heat exchanger is operated in vacuum state, the design pressure of vacuum layer shall be considered according to the bore external pressure and when the safety control device is installed, the design pressure is taken with the minimum value of 1.25 times of the maximum internal and external pressure difference and the 0.1MPa; when no safety control device is installed, it shall be taken as 0.1MPa.

3.4.2 Design temperature

3.4.2.1 The increase of internal thermal stress shall not exceed the ultimate strength of material and the maximum recommended allowable temperature difference is 50°C between the aluminum heat exchanger layers (on the same section) in the steady state; However, for the fluid with phase change and instant circulation, the recommended temperature difference shall be 20°C~30°C.

3.4.2.2 When the design temperature is not greater than 65°C, the aluminum alloy with magnesium content of more than 3% shall not be adopted.

3.4.2.3 The design temperature shall not be less than the maximum temperature attained by the parts metals under operating conditions. For the metal Temperature of below 0°C, the design temperature shall be -269°C at the lowest.

3.4.2.4 When the metal temperatures of heat exchanger parts are different under operating conditions, the maximum temperature shall be complied with to design. In any case, the metal surface temperature of parts shall not exceed the allowable service temperature of material.

3.4.2.5 The metal temperature of parts may be attained by heat transmission calculation or measured on the heat exchanger in the same applied working condition or determined according to the medium temperature. For the heat exchanger in different working condition, it shall be designed according to the harsh working conditions group; the pressure and temperature values in the working conditions shall be indicated in the drawing or corresponding technical provisions.

3.4.3 Fluid medium

The media characteristics used in the operational process shall be restricted. The fluid shall be clean and free of corrosive action to the aluminum alloy; generally the corrosion allowance is not taken into consideration. The media which can easily be scale formed, settled and block the heat exchanger shall be controlled.

3.4.4 Load

The following loads shall be taken into consideration in design:

determined according to those specified in JB/T 4734 or according to the mechanical property and safety factor as provided by the corresponding standards; for the materials of pressure parts, such as heat transfer fin and parting sheet, it shall be determined by dividing the tensile strength value as specified in GB/T 3198 and YS/T 69 by the safety factor 4~6.

3.6 Welded joint factor

The welded joint factor φ shall be determined according to the welding method and welded joint mode of pressure parts as well as the linear scale of nondestructive test:

a) For the butt joint of both sides welding and the full penetration butt joint equivalent to the both sides welding:

The 100% nondestructive test φ=0.95;

Partial nondestructive test φ=0.8.

b) The joint of single welded butt joint (stool plate is closely clung to the base metal along the seam root full length):

100 % nondestructive test φ=0.90;

Partial nondestructive test φ=0.8.

When the welded joint couldn't be carried out with nondestructive test due to structure, full penetration structure shall be adopted for the welded joint and the welded joint coefficient is generally not greater than 0.6.

3.7 Pressure test

Pressure test shall be carried out after the heat exchanger is manufactured. The manner, requirements and test pressure of pressure test shall be indicated in the drawing.

The pressure test is generally adopted with hydraulic test and the testing liquid shall be carried out according to those specified in 6.2.

For the heat exchanger which is not allowed to have residual liquid or the hydraulic test couldn't be carried out with full liquid due to structure may be adopted with the pneumatic test. The heat exchanger to carry out pneumatic test and leakage test shall be in accordance with those specified in 6.2.

3.7.1 Test pressure

Where:

p_T -- The test pressure, MPa;

p -- The design pressure, MPa;

3.7.1.3 The pressure test with special requirements

For the heat exchanger which bears alternate load or is applied in special situations, the hydraulic test pressure shall be suitably raised and the specific requirements shall be carried out according to those specified in the drawing.

3.8 Drawing

The outside drawing of product provided by the manufactory shall be equipped with all the data that is required for the buyer examination and mainly includes:

a) Physical dimension, material thickness, model specification, heat interchanging area, layer volume, support and weight;

b) The designation specification of material and the heat transfer fin type of applied heat transfer fin;

c) Position of nozzle and flange, connection details and types of all fluids if necessary;

d) Manufacturing and testing data, range and position of nondestructive test, test pressure and welding seam identification.

4 Materials

The materials for heat exchanger shall be taken into consideration with the operating conditions (such as design temperature, design pressure, media characteristics and operating feature), manufacture process and inspection requirements of heat exchanger as well as the economical rationality; it shall also be provided with favorable corrosion resisting property, mechanical property, welding property, shaping property and other processing properties and physical properties. For the specified, the relevant requirements as specified in JB/T 4734, GB/T 3198 and YS/T 69 shall be taken as the reference.

5 Design

F_x -- the component force on the interior section of x direction from nozzle to header, N;

F_y -- the component force on the interior section of Y direction from nozzle to header, N;

F_z -- the component force on the interior section of Z axis direction from nozzle to header, N;

h_1, h_2 -- the folding height of slab composite header, mm;

h -- the height of transitional short piece, mm;

H -- the height of slab composite header, mm;

L -- the longitudinal width of rectangular bottom surface for the composite header, mm;

M -- the calculated resultant moment on the interior section from nozzle to header, N·m;

M_r -- the allowable resultant moment on the interior section from nozzle to header, N·m;

M_x -- the component moment on the interior section of x direction from nozzle to header, N·m;

M_y -- the component moment on the interior section of Y axis direction from the nozzle to header, N·m;

M_z -- the component moment on the interior section of Z axis direction from nozzle to header, N·m;

p -- the design pressure, MPa;

Ri -- the internal radius of header body, mm;

R_p -- the calculation radius of slab-shaped header with ends, mm;

δ_p -- the thickness of slab-shaped header with ends (including additional value of wall thickness), mm;

α -- the slope angle of oblique slab-shaped header with ends, $45° \leq \alpha \leq 90°$;

5.1.8 Wall thickness calculation and strength check

5.1.8.1 Wall thickness calculation of curve header with ends and header body (Figure 5.3):

When $d_i/D_i \leq 0.5$, the calculation shall be calculated according to Formula (5.1):

$$\delta = \frac{pR_i}{[\sigma]^t \phi - 0.6p} + C \tag{5.1}$$

Therein φ=0.6.

5.1.8.2 The wall thickness of header body of the header as shown in Figure 5.4~Figure 5.6 shall be calculated according to Formula (5.1). For the certain design wall thickness δ of the header shown in Figure 5.7, each design size shall be carried out with the stress check before pressure test unless that effective stress analysis has been made or the experienced formulae is adopted.

The circular cylinder stress shall be checked according to Formula (5.2) before the pressure test:

$$\sigma_T = \frac{p_T(R_i + 0.5\delta_e)}{\delta_e} \tag{5.2}$$

Where:

σ_T -- the circular cylinder stress under test pressure, MPa;

R_i -- the interior diameter and radius of circular cylinder, mm;

p_T -- the test pressure, MPa;

δ_e -- the effective thickness of circular cylinder, mm.

Σ_T shall meet the following conditions:

In hydraulic test:

$\sigma_T \leq 0.9\varphi R_{0.2}$

In pneumatic test:

$\sigma_T \leq 0.8\varphi R_{0.2}$

b) If a certain flow velocity is required to maintain and the nozzle diameter is restricted, several nozzles may be welded on the same header;

c) To prevent or reduce the erosion to the aluminum members on the heat exchanger inlet and outlet, the flow velocity limit shall be taken into consideration;

d) When the external nozzle diameter of heat exchanger is less than 40 mm, the structure form of processing the rod into socket welding nozzle. For the tangential nozzle, the flow area between nozzle and header shall not be less than the sectional areas of nozzle.

5.8.2 Nozzle installation

When the nozzle is installed, the fluid in the pressure ports shall be discharged completely. If necessary, discharge joint shall be additionally installed on the header or connecting pipe to install outlet- check valve.

5.8.3 Nozzle load

When the nozzle of heat exchanger is added with force and force moment by the connecting pipe, the maximum force and force moment of such parts as nozzle and header shall be checked by the manufactory.

The total resultant force F and the resultant moment M shall be calculated and determined according to Formula (5.5)~(5.7).

$$M = \sqrt{M_x^2 + M_y^2 + M_z^2} \tag{5.5}$$

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2} \tag{5.6}$$

And:

$$(M/M_r)+(F/F_r)\leq l \tag{5.7}$$

See Figure 5.17 for the three coordinate axes positions.

d) When assembling, each seriate braze welding component shall be drawn aside with each other, but not wrap. When the design pressure $p \leq 2.5MPa$, the splicing gap of the braze welding cellular shall not be larger than 1.5mm, and the part shall not be larger than 3mm, and when the design pressure $p > 2.5MPa$, the splicing gap of the braze welding cellular shall not be larger than 1mm, and the part shall not be larger than 2mm. The special requirements of splicing gap shall be noticed in the pattern.

6.1.3.2 Joint brazing procedure

The establishment of the joint brazing procedure shall be carried out according to the qualified evaluation of the joint brazing procedure.

6.1.3.3 Appearance of the block

a) The welded joint of the block shall be satiation and smooth, the phenomenon which the spelter blocked the channel shall be avoided.

b) The wing shape of the distributor fin shall be regular, and shall not come out of the parting sheet.

c) The cove of the side bar between two adjacent floors which outer flip quantity shall not excess 2mm;

d) The dislocation quantity of the upper and lower plane of the block shall be no larger than 1.5mm of each 100mm, and the total dislocation quantity shall be no larger than 8mm.

e) The total amount of the inferior fovea pleural shall not excess 1% of the block lamination gross thickness.

6.1.4 Welding

6.1.4.1 Type of welded joint

The welded joint type shall be chosen according to the medium temperature and loading conditions, when choosing the welded joint type, the generation of oversized stress concentration and obvious profile revulsion shall be avoided, the alternative welded joint type is provided in annex B.

6.1.4.2 Welding process

a) The welding procedure qualification before the construction of heat exchanger shall be carried out according to the JB/T 4734 in annex. The welding process

6.1.7.4 The welded joint of nozzle and flange, if any one of the two needs to adopt the heat treatment to improve the mechanical strength of materials, penetrant testing shall be carried out according to JB/T 4730.5, and Level I is qualified.

6.2 Test, inspection and acceptance

The test procedures shall be carried out according to those specified in Annex A of this standard.

The check and test of heat exchanger shall not only be carried out at the field installations according to the item requirements, but also shall be carried out in manufacturer, each heat exchanger needs to be tested by the technical control department of manufacturer (and the third party), and the quality certificate is needed before leaving the factory.

6.2.1 Requirements of pressure meter

The pressure meter which have two uniform measurement ranges and qualified after verification shall be applied during the pressure test. The manometric measurement range shall be around two times of the pressure testing pressure, but shall not be 1.5 times lower and four times more than the test pressure.

6.2.2 Compressive strength test

The test for pressure drop across the heat exchanger shall not only be in accordance with this standard or the special stipulation of the drawing, but also shall be in accordance with those specified in "Technologic Supervision Regulations on Safety of Pressure Vessels".

The pressure test shall be carried out after the accomplishment of the heat exchanger manufacture, and the item and requirements of the pressure test shall be noted in the pattern.

6.2.2.1 Hydraulic pressure test

The water shall be generally adopted as the testing medium in the heat exchanger hydraulic pressure test, and the water shall be clean and no corrosive to the workpiece.

The test pressure shall meet the requirements of 3.7.1. When testing, the test shall be carried out in the channel one by one, when one of the channels is pressurizing, others shall be emptied, and the check shall meet the requirements in accordance with those specified in the pattern.

$$[(\triangle p_{big}/\triangle p_{little})\text{-l}]\times 100\%\leq 8\% \tag{6.1}$$

Where:

$\triangle p_{big}$ -- the one with bigger pneumatic resistance value in channel A, B (same below);

$\triangle p_{little}$ -- the one with smaller pneumatic resistance value in channel A, B (same below);

6.2.4.2 The gross resistance deviation of the switching channel within two little unit combined by cold and hot leg (including cold, hot leg tandem entirety heat exchanger) shall be calculated according to Formula (6.2).

$$[(\triangle p_{big}/\triangle p_{little})-1]\times 100\%\leq 2.4\% \tag{6.2}$$

6.2.4.3 After the combination of several little units, the deviation of resistance value of each channel and the average value of corresponding channel in the big unit shall be calculated according to Formula (6.3).

$$[(\triangle p_i/\triangle p_{cp})-1]\times 100\%\leq\pm 4\% \tag{6.3}$$

Where:

$\triangle p_i$ -- the pneumatic resistance value of one tested channel.

$\triangle P_{cp}$ -- the mean resistance value of one tested channel, calculate according to Formula (6.4).

$$\triangle P_{cp}=(\sum_{i=1}^{N}\triangle p_i/N) \tag{6.4}$$

Where:

N -- the combined group number in the cold and hot leg.

6.2.5 Fluoroscopic inspection

This test needs to be carried out when it is required in the heat exchanger design graph or delivery contract.

As to the channel which for the operating of oxygen gas in heat exchanger, degrease treatment is need to be carried out, and after the accomplishment of the heat exchanger, the inspection is carried out which adopt the ultraviolet ray with wavelength of 3200Å~4000 Å to check out the Surface, header and nozzle inside of the channel header of the heat exchanger below, to prove the fluorescence evidence caused by non-hydrocarbon.

2 times, if more than 2 times, relevant welding procedure qualification report is needed. The metal of defect part shall be eradicated before repairing welding, and the weld zone should be recleaned up, even repairing welding with pressure is no allowed.

b) As to the space division device like the switch heat exchanger, main heat exchanger, condenser-evaporator and the heat exchanger unit body which design pressure is larger than 2.5MPa, the allowable solder joint repairing welding length shall not be larger than 0.5% of the total length of the reveal parting sheet (containing the inside of the header), and as to other heat exchanger, the allowable repairing welding length of the solder joint shall not be larger than 1.5% of the total length of the reveal parting sheet (contain the inside of the header).

6.4 Quality certificate, mark, painting, package, transportation and storage

6.4.1 Preparation work before leaving the factory

6.4.1.1 Cleanness

The oil stain and dirt shall be removed to maintain cleanness at the external surface of product. Painting and other anticorrosion treatment shall be in accordance with the design graph and those specified in relevant technical documents.

6.4.1.2 Drying

The manufacturer shall be sure of all the pressure port intensive drying of heat exchanger before transportation; specific requirements shall be carried out according to those specified in annex A.

6.4.1.3 Flange protection

All the reveal treating interface of flange shall be proper protected to prevent from mechanical damage, especially the flange sealing surface.

6.4.1.4 Protection of dummy layer and dead area

The opening of the dummy layer and dead area, the opening of the closed dead area shall be properly protected to prevent from moisture and dust irruption.

6.4.1.5 Nitrogen seal

a) The pressure port of heat exchanger which is qualification after drying, dry and oil-free nitrogen shall be filled for the replacement and nitrogen seal, the

The supporter is generally installed on the upper part of block (core) (heat exchanger core), thus reducing the shake between the bracket and support slat junction when the device is started or stopped.

In addition to the main supporter, when the sliding guide-frame is required to be added, it shall be installed according to the structure as shown in Figure 7.1 and 7.2 and the following factors shall be taken into consideration:

a) Physical dimension of heat exchanger;

b) Weight of heat exchanger;

c) Site conditions (Earthquake, wind power and pipe load);

d) The relative position of the main supporter plane and the heat exchanger centre of gravity.

The external force and moment of force that are allowed to be exerted at the junction between header and nozzle of heat exchanger shall be provided by the manufactory when it is required by the buyer. The buyer shall ensure that the loads of all the connecting pipes shall not exceed the value provided by the manufactory.

7.2 Hoisting and transportation

The heat exchanger shall be installed with hoisting devices and the precautions shall be provided by the manufactory when the heat exchanger is hoisted and transported.

7.3 Supporting bracket

The installation of supporting bracket shall be in accordance with the following requirements:

a) Heat exchanger shall be installed on the supporting bracket. In addition to the heat exchanger deadweight, the force and moment of force exerted by the external shall be taken into consideration when the supporting bracket is selected.

b) The verticality deviation of the heat exchanger installed on the supporting bracket shall not be greater than 0. 5° or 15 mm and the verticality may be adjusted by padding the sheet metal.

c) The matching surface between supporting bracket and heat exchanger shall be thermal insulated and the thermal insulating material strength shall be attuned to the bore load and shake; the thermal insulating material thickness shall be

Angle Bracket

7.5 Fixed bolt

The bolt shall be adopted to fasten when the heat exchanger is installed on the supporting bracket and the increase of force and moment of force due to thermal expansion and contraction shall be taken into consideration when it is fastened.

7.6 Dead layer opening

7.6.1 The following dead layers shall be set with opening:

a) Dummy layer;

b) The space between the adjoint two headers at the block (core) side;

c) The dead angle formed after the distributor fin at head end is adopted with oblique side bar;

d) The space formed when the two block (core) are parallel connected (welded) together;

e) Other special structures.

7.6.2 The opening shall be marked and guaranteed that the dead layer cavum shall be passage clear and the opening shall be carried out with drying and seal treatment before transportation.

7.6.3 The sealing stuff (such as screw, spill or waterproof membrane and so on) covered on the opening shall be removed before the site test and operation and whether the discharge pipe shall be installed or not shall be determined as required.

7.7 Inspection and test

7.7.1 Installation inspection

Visual inspection shall be carried out for the welded joints after the installation is finished; penetration or radiographic testing may be carried out when the customer requires and the inspection shall be in accordance with the requirements in the relevant standards.

7.7.2 Pressure test

The pressure test shall be carried out after the installation, and it shall meet the shall not be larger than 2°C/min in order to avoid the thermal shock to system, the cooling gas shall be introduced to each layer simultaneously and the temperature difference between cooling gas temperature and partial metal temperature shall not exceed 30°C;

e) The initiation data shall be recorded and filed.

7.9.2 Operation

Operation shall be in accordance with the following requirements:

a) The fluid inlet shall be installed with a filter apparatus and a bypass system; the filtering net shall at least be able to remove the solid particulate and dirt with diameter greater than 0.18 mm;

b) The fluid flow in system shall remain firm in order to avoid the direct impact of impulse or surging air flow from compressor or pump;

c) The release pressure of pressure relief devices shall not be larger than the maximum allowable working pressure and the release pressure setting value and relieving capacity shall be in accordance with the requirements in relevant standards.

7.9.3 Parking

Parking shall be in accordance with the following requirements:

a) The fluid in the system shall be drained after parking and dry gas shall be adopted to raise the system temperature; the heating rate shall not be larger than 2°C/min and the instant temperature difference between heating gas and system shall be strictly controlled and shall be not greater than 50°C;

b) Stopping temperature rise when the system attain normal temperature and the dry gas or and nitrogen with dew point no greater than-40°C shall be adopted to blow down.

c) Nitrogen seal shall be considered for the system when parking requires a long standing after blowing down.

7.10 Preventive maintenance

Preventive maintenance shall be in accordance with the following requirements:

a) Operating conditions of heat exchanger shall be recorded and the content shall

7.11.2 Site pressure test and leakage detection

Before the fieldwork starts, all be layers shall be blown down by dry nitrogen or dry air. Gas analysis shall be carried out to ensure that no residual harmful gas exists in the system. If the heat exchanger is installed in the cold box, the top and bottom air outlet hole of the cold box shall be able to discharge air and the oxygen content shall be continuous monitored; when the oxygen content is less than 19 %, it is forbidden to enter.

Each layer shall be sealed with blind plate and installed with appropriate pressure gage and then pressurize to each layer in turn; The initial test pressure shall be set with the maximum 0.5MPa (gauge pressure), because most of the leakage may be detected in low pressure. Higher pressure may be adopted to carry out the test according to the leakage conditions; however, the test pressure shall not exceed the working pressure of this layer. Testing medium shall be adopted with dry nitrogen or dry air.

All the mechanical joints shall be confirmed to have no leakage after the pressure is filled. Maintain the pressure for 10h~12h, if the pressure drops but not caused by temperature change, leakage may be confirmed. The pressure maintaining time depends on the sensitivity level of pressure gage and the capacity of test layer. Concurrent with this, if the pressure of adjacent layer is increased, it may be confirmed that internal leakage occurs between layers. If the pressure of adjacent layer does not increase, external leakage may be confirmed. All the layers shall be installed with pressure relief devices in case of super-pressure.

When such leakage detection method is adopted, requirements in 7.7.2 shall be complied with and preventive measures shall be taken at the same time to make sure that the leakage may not replace the oxygen gas in confined space or the combustible atmosphere is formed.

The recorded pressure shall be adjusted according to the method as stated in 7.7.2 to compensate for the ambient temperature change during test period.

The external leakage may be determined by adopting the method as stated in 7.7.2 by using the soapy water to test the newly arranged pipe welded joint.

7.12 Mending of leakage

Qualified welder shall carry out repairing welding according to repairing welding technique for the external leakage.

If internal leakage is required to mend in heat exchanger, it shall propose and negotiate restoration suggestion and method with the manufactory.

discharged before test and then increase pressure slowly. The dummy layer which is not tested shall be open to atmosphere;

c) When the pressure is increased gradually to the 2 times of the designed maximum allowable design pressure, the pressure shall be increased to 4~6 times of the maximum allowable design pressure in an incremental quantity of 0.5 MPa. When it is pressurized to 4~6 times of the fitted maximum allowable design pressure and the test unit is not broken, it shall be pressurized till the burst occurs and the pressure value shall be recorded as soon as the burst is happening. Finally, the maximum allowable design pressure of tested heat transfer fin shall be calculated according to A.1.1.5 by the design department. The designer and examiner shall be present during the test and the sign on the manufactory test report (recommended sample table of test report may be in accordance with Table A.1). The report shall be detailed, including test equipment, instrument and the results. Then the report shall be filed as technological document.

A.1.1.4 Cutout inspection shall be carried out for the sample piece when the burst is carried out; if the burst form is heat transfer fin tensile failure, the test is qualified. If it is brazing seam disconnection, the test shall be carried out again.

A.1.1.5 Assessment:

a) The maximum allowable design pressure of this tested heat transfer fin shall be calculated;

$$[p]=\frac{p_b}{n_b}\times\frac{R_m}{R_{mp}} \tag{A.1}$$

Where:

$[p]$ -- the maximum allowable design pressure, MPa;

p_b -- the bursting pressure of sample piece, MPa;

R_m -- the minimum standard tensile strength of this material at room temperature, MPa;

R_{mp} -- The actual measured average tensile strength of the tested heat transfer fin at room temperature, MPa;

n_b -- The safety factor, the value of which shall be selected according to A.1.2.3;

b) If a lot heat transfer fin is made of material with the same boil lot number and the sample piece made of such heat transfer fin is carried out with test, the maximum

1 -- Compressed gas cylinder; 2 -- Decrement gauge; 3, 7 -- Glass rotameter; 4 -- Heat exchanger; 5, 6 -- Valve; 8 -- Dew-point meter

Figure A.1 -- Dew Point Testing Device Diagram

A.2.2 Testing instruments and equipment:

a) Compressed gas cylinder;

b) Decrement gauge;

c) Dew-point meter, ± 1°C;

d) Valve;

e) Glass rotameter

A.2.3 Test procedure

Fill dry, oilless and clean air or noble gas with below -30°C dew point into each channel. The flow through dew-point meter is 10 L/min. And then measure the dew point of exhausted gas with dew-point meter.

A.2.4 Test assessment

The below -5°C dew point of each channel shall be qualified. If the contract has requirements for dew point value, it shall be implements according to specified value in contract.

A.3 Air resistance test

A.3.1 Overview

Fill natural air with specified flow into measured channel and measure the inlet and outlet pressure difference of this channel under experiment condition. And then assess the possibility of achieving the air resistance value of this channel under design conditions. The imbibition method shall generally be adopted, and see Figure A.2 for the device.

with full opening; start blower 6, and then adjust valve 5 to make air flow through specimen change from small to large. When the difference of air flow and specified value by drawing is less than 2%, the adjustment shall be stopped. Stabilize 5min, record the value of T_1, T_2, $\triangle h_l$ and $\triangle h_2$. Continuously record three groups of numeric value every other 5min. And record the temporal atmospheric pressure p and relative humidity φ.

A.3.5 Calculation

A.3.5.1 Adopt the mean value of three groups of data as the test value, namely T_{1test}, T_{2test}, $\triangle h_{ltest}$ and $\triangle h_{2test}$.

A.3.5.2 Conversion of test air resistance value

A.3.5.2.1 The calculation of test temperature T_{test} shall be carried out according to Formula (A.2):

$$T_{test}=(T_{1test}+T_{2test})/2 \tag{A.2}$$

Where:

T_{test} -- the mean temperature of air for test, K;

T_{1test} -- the temperature of specimen air inlet for test, K;

T_{2test} -- the temperature of specimen air outlet for test, K

A.3.5.2.2 The test air flow Q_{test} shall be calculated according to $\triangle h_1$ and iteration adopting computer in Annex E and G-G of GB/T 2624.

A.3.5.2.3 If the measured air resistance value is needed to reduce to specified air resistance value by design drawing under experiment condition, it shall be carried out according to Formula (A.3).

$$\triangle h=\frac{Q_{2drawing} \times T_{drawing} \times p_{test}}{Q_{2test} T_{test} p_{drawing}} \times \triangle h_{2test} \tag{A.3}$$

Where:

$\triangle h$ -- the air resistance value specified in design drawing under experiment condition, Pa;

P_{test} -- the air pressure under test condition, Pa;

$T_{drawing}$ -- the air temperature specified by design drawing, K;

measured channel), first measure the channel with maximum pressure difference, pressurize to design pressure with air (slowly increase pressure for high pressure), stop more than 10min after pressure reaching to observe pressure gage indication stability (make temperature balance), and then connect U-tube differential pressure gauge, strictly seal each joint and begin to record. The thermometer shall be set in the specimen. After recording the value of value of pressure gage, U-tube differential pressure gauge, thermometer and air gauge, the standing time is no less than 8h, and then the indication above each gauge shall be recorded.

If necessary, select the secondary high channel higher than measured channel pressure (channel with submaximal pressure difference) again, pressurize, and then calculate the leak rate between two channels. And so on, the leak rate of all channels higher than measured channel pressure and measured channel may be gained. And the leak rate of measured channel is equal to the sum of all leak rates.

A.4.3.2 Data record

The following data must be recorded when adopting U-tube leak test:

a) Starting time T_0, temporal atmospheric pressure p_0, internal temperature of heat exchanger t_0 (°C);

b) Ending time T_1, temporal atmospheric pressure p_1, internal temperature of heat exchanger t_1 (°C);

c) U-tube difference of measured channel U (mmH_2O), volume of measured channel V (L).

A.4.4 Calculation method:

a) The theoretical pressure difference for no leakage shall be calculated according to Formula (A.4):

$$\triangle h=[p_0\times(t_1+273.15)/(t_0+273.15)-p_1]\times10^4 \qquad (A.4)$$

Where:

$\triangle h$ -- the pressure change value of U-tube differential pressure gauge for theoretical no leakage, Pa;

p_0 -- the measured atmospheric pressure for test beginning, Pa;

p_1 -- the measured atmospheric pressure for test ending, Pa;

Simultaneously, the instrument sensitivity shall be debugged. And then the instrument background signal $A_{background}$ shall be measured.

A.5.4.1.4 Measure the output signal of standard leak hole in helium mass spectrum meter $A_{standard}$.

A.5.4.1.5 Vacuumize measured channel to below 1.33Pa when reaching standing time, and measure the leak rate signal A_{test} of measured channel.

A.5.4.2 Internal leak (series leak of channel) inspection

A.5.4.2.1 The equipment and instruments shall be connected according to Figure A.4.

A.5.4.2.2 Fill helium gas or helium-nitrogen mixture into adjacent channel of measured channel and increase pressure to the air tight test pressure of this channel.

A.5.4.2.3 Vacuumize measured channel to below 1.33Pa and maintain pressure 1h.

A.5.4.2.4 Debug the instrument sensitivity during pressure maintaining time. Simultaneously, measure the instrument background signal $A_{background}$ and standard leak hole signal $A_{standard}$.

A.5.4.2.5 Measure the signal A_{test} of measured channel helium mass spectrum meter after below 1.33Pa measured channel pressure and 1h pressure maintaining.

A.5.5 Calculation and test assessment

A.5.5.1 The leak rate shall be calculated according to Formula (A.6):

$$Q=\frac{A_{test}-A_{background}}{A_{standard}}\times Q_{standard} \qquad (A.6)$$

Where:

Q -- the leak rate, P·L/s;

$Q_{standard}$ -- the leak rate of standard leak hole, P·L/s;

A_{test} -- the measured signal of measured channel, mV;

$A_{standard}$ -- the measured signal of standard leak hole, mV;

$A_{background}$ -- the measured background signal of instrument, mV

Annex D

(Informative)

Application Instruction of Heat Exchanger

D.1 Thermal stress of heat exchanger

D.1.1 The manufacturer shall design each heat exchanger according to planned design pressure and provide buyer with detailed description of allowable external loading exerted on heat exchanger in field. The heat exchanger shall adapt all possible loading during operation, including pressure loading, external loading (namely force and moment applied by pipeline) and thermal stress caused by thermal induction loading.

Under standard and non-standard application condition, this annex will recommend some methods in order to make total combined stress maintain within permissible limit so that some measures may be adopted during heat exchanger application.

D.1.2 Mechanical failure

Each component of heat exchanger is mutually connected with tight rigidity of each direction; therefore, the partial metal temperature difference generated in each component and between components of heat exchanger may cause large thermal stress of these components.

The partial metal temperature difference is caused because these components or partial components heat up or cool at various velocities with heat input (change). The temperature differences may generate instant expansion or shrinkage in components or between components and the machinery restricts the movement of member generated by heat to result in the thermal stress in components. If the partial metal temperature difference is large, the thermal stress and other external bearing stress may exceed yield stress and may exceed ultimate stress of materials.

Temperature difference of adjacent components of heat exchanger may generate obvious thermal stress owing to the following reasons:

a) Continuous unstable condition: such as, the flow fluctuation is large, the flow in boiling channel is instable, and the equipment control system is not proper;

b) Transient condition: such as start, shut-down, equipment interference, defrosting, cooling and heating.

cause the instability of flow. Therefore, the allowable temperature difference suggested by manufacturer for those heat exchangers with complete evaporation shall be strictly complied with, and the design of process equipment shall ensure the stability of flow.

e) The design and operation process equipment as well as pipe connecting with heat exchanger shall all prevent flow deviation and instability (for example: the liquid entering into heat exchanger has discontinuity stagnation), which is very important for boiling flow;

f) The periodic or frequently alternating temperature fluctuation of any fluid shall be limited within ± 1°C/min.

D.1.4 Summarization

The heat exchanger is a kind of firm and durable heat exchanger that can bear large temperature difference between stable fluids. Because the heat exchanger is tight rigid structure, if the heat exchanger operates under discontinuity or continuity instability condition, the oversize thermal stress may be generated to damage the heat exchanger. The oversize thermal stress may be avoided by following above several suggestions, which is helpful for ensuring the service life of heat exchanger.

D.2 Fouling and blocking problems of heat exchanger

D.2.1 Fouling problem

The heat exchanger generally may not touch pollution problem, because it is usually used for space division, hydrocarbon separation and gas liquification.

If the pressure falling of product has no large change, but the heat transfer property falls, it may be fouling problem. If this problem appearing, the following measures may be suggested:

D.2.1.1 Preventive measures

Before determining to apply the heat exchanger, it shall be inspected if the liquid has solid and extraneous matter to prevent deposition forming during application, and is shall be especially noticed for low temperature area.

It is very important to consider the pollution caused by impurity existing of process liquid, and the typical example is the seal oil used in refrigerant. It may deposit on finned surface with solid film and lower the heat transfer property of heat exchanger.

The gas containing drop nitrogen oxide (NO_x) shall not be used, because it may be influence the property of heat transmission and pressure dropping (resistance).

The blocked channel generally can be identified soon, the maintenance plan can be prepared and may be implemented at shut-down. The mechanical method removing stemming from heat exchanger may be required for air or nitrogen blowdown.

a) Back blowing blocked channel: install one bursting piece at channel inlet, raise blowdown air (or nitrogen) pressure up to bursting piece breaking (this operation shall be carried out repeatedly up to no particle discharge in blowdown air);

b) Or "blocking device" may be set at heat exchanger outlet. It is composed by one quick opening valve and air with fixed quantity and pressure. The shock wave shall be generated in heat exchanger core to clear stemming during operation.

If the blocking is severe, each channel opening may be connected with "blocking device" to discharge stemming adopting blocking discharge method.

The solvent and gas foaming methods utilizing the mechanical energy provided by air generated in filled liquid so as to eliminate the particles.

D.3 Corrosion problems

The heat exchanger may be satisfactorily used for a lot of technology process without corrosion problems. But as the same as other heat exchangers, the heat exchanger may also generate corrosion problems. If corrosion problems appear, the selection and operating ambient of process fluid shall be noticed. The buyer/operator shall connect with manufacturer in order to determine applied optimal plan to avoid corrosion problems.

D.3.1 Process environment containing water

For those parts of heat exchanger operated below freezing point of water, the corrosion phenomenon may mainly be caused by water or containing water, which may stop or carry out no longer. Owing to the water pureness change and suffusion, the ice point temperature may not be 0°C. Other factors shall be taken into account for above ice points, such as defrosting. The influence of water may be divided into three classes:

D.3.1.1 Influence of water in neutral environment

The heat exchanger may be extensively used for a lot of hydrate technology process and contain water, the water maintain neutral (pH 6~8) in heat exchanger even in halogen environment, and the adaptability of heat exchanger owning the neutral water as process fluid may be influenced by heavy metal content and deposit degree of cannot react with aluminium. However, if the mercury exists in heat exchanger with liquid state and containing water, the mercury impurity may cause a lot of problems. If the mercury corrosion is connected with another corrosion process, the consequence is very severe.

Another problem caused by mercury existing in process fluid is: the mercury may react with aluminum alloy with high content magnesium, and the mercury can rapidly start the second phase reaction with magnesium basis in alloy aluminium under waterless condition. If the part design of equipment does not consider these problems and conditions, it may be helpful for the corrosion failure of mercury and may generate damage under the level lower than required stress under no mercury condition.

Many heat exchangers may be successfully applied to the occasion containing mercury fluid owing to adopting effective protective measures. The buyer may use the purchased device from the market to clear the mercury in raw gas. The operator may also adopt some special enclosure methods, such as adopting nitrogen enclosure to prevent and avoid water vapor in metallurgy. Such as raising temperature above 100°C for a long time during defrosting to avoid and prevent water vapor generation.

The manufacturer may provide some detailed alternative schemes for equipment containing mercury, such as trying to eliminate mercury forming and stacking during component design, and trying to avoid using the alloys with sensitive reaction. If these methods cannot be put into effect, some preventive measures may be adopted to isolate or protect the magnesium containing alloy free from mercury corrosion.

D.3.3 Atmosphere or environmental corrosion

The heat exchanger of any device generally has no obvious atmospheric corrosion evidence. However, if the heat exchanger is put in the humid environment with temperature change, the heat exchanger surface may have slight natural corrosion caused by wet vapor coagulation.

If the heat exchanger is exposed in salinity water fog or salt atmosphere environment, for example, if the heat exchanger is stored in site period of coastland for a long term or packing period without adapting the shipping during marine transportation, the special protective measures shall be adopted. If the heat exchanger is transported by marine with complete set, all surfaces of heat exchanger shall be immediately washed with low chlorine water (chlorine content is less than 25mg/L) after reaching site, and the manufacturer shall inform the detailed methods related to heat exchanger unit washing. After washing, the surface shall be airdried thoroughly.

Because it is very difficult to ensure the insulated component of any heat exchanger not to leak water, the security of insulated component is using water to control the easy fire causing. Therefore, it is very important to make heat exchanger not expose

------ The End ------