Shell-and-tube Heat Exchangers for General Refinery Services

API Standard 660, Seventh Edition, April 2003

ISO 16812:2002 (E), Petroleum and natural gas industries—Shell-and-tube heat exchangers

American
Petroleum
Institute

**Helping You
Get The Job
Done Right.**SM

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Downstream Segment, telephone (202) 682-8000. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the general manager of the Upstream Segment, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

API Foreword

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the Standardization Manager, API, 1220 L Street, NW, Washington, DC 20005.

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16812 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Annexes A, B, C and D of this International Standard are for information only.

Introduction

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

In International Standards, the SI system of units is used. Where practical in this International Standard, US Customary units are included in brackets for information.

A bullet (●) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on data sheets or stated in the inquiry or purchase order (see examples in annex A). Decisions should be indicated on a check list (see example in annex B). Annex C contains an example of a checklist which can be used to indicate the responsibilities of the various parties.

Petroleum and natural gas industries — Shell-and-tube heat exchangers

1 Scope

This International Standard specifies requirements and gives recommendations for the mechanical design, material selection, fabrication, inspection, testing and preparation for shipment of shell-and-tube heat exchangers for the petroleum and natural gas industries.

This International Standard is applicable to the following types of shell-and-tube heat exchangers: heaters, condensers, coolers and reboilers.

This International Standard is not applicable to vacuum-operated steam surface condensers and feed-water heaters.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ASME B 16.5[1)], *Pipe flanges and flanged fittings: NPS ½ through NPS 24*

ASME B 16.11, *Forged fittings, socket-welding and threaded*

ASME B 1.20.1, *Pipe threads, general purpose (inch)*

NACE MR0175[2)], *Sulfide stress cracking resistant metallic materials for oilfield equipment*

TEMA[3)], Eighth edition, *Standards of the Tubular Exchanger Manufacturers Association*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
heat exchanger unit
one or more heat exchangers for a specified service that may include alternative operating conditions

---

1) ASME International, 3 Park Avenue, New York, NY 10016-5990, USA.

2) NACE International, P.O. Box 218340, Houston, TX 77218-8340, USA.

3) Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, NY 10591, USA.

3.2
item number
purchaser's identification number for a heat exchanger unit

3.3
effective surface
outside surface area of the tubes that contributes to heat transfer

3.4
nubbin
projection on the flange gasket surface, positioned at the centre of the gasket, used to concentrate the bolt load on the gasket

3.5
pressure design code
recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME Boiler and Pressure Vessel Code, Section VIII.

3.6
seal-welded
welded to improve leak tightness of tube-to-tubesheet joints

3.7
strength-welded
welded so that the design strength is equal to, or greater than, the maximum allowable axial tube strength of tube-to-tubesheet joints

3.8
category A welded joint
longitudinal welded joint within the main shell, communicating chambers, nozzles or transitions in diameter; or any welded joint within a sphere or within a formed or flat head; or circumferential welded joint connecting hemispherical heads to main shells, to transitions in diameters or to communicating chambers

3.9
category B welded joint
circumferential welded joint within the main shell, communicating chambers, nozzles, or transitions in diameter including joints between the transitions and a cylinder at either the large or small end; or circumferential welded joint connecting formed heads, other than hemispherical to main shells, to transitions in diameter, to nozzles or to communicating chambers

3.10
communicating chamber
heat exchanger appurtenance which intersects the shell or heads of the heat exchanger and forms an integral part of the pressure-containing envelope

EXAMPLE Sump.

3.11
full-penetration weld
butt joint attained by double-welding or by other means which provides the same quality of deposited weld metal on the inside and outside surfaces to meet the requirements of the pressure design code

4 General

● **4.1** The pressure design code shall be specified or agreed to by the purchaser. Pressure components shall comply with the pressure design code and the supplemental requirements given in this International Standard.

4.2 Heat exchanger construction shall conform to TEMA Standards, Class R, unless another TEMA class is specified.

● **4.3** The vendor shall comply with the applicable local regulations specified by the purchaser.

4.4 If specified by the purchaser or required by local regulations, the vendor shall register each exchanger with the appropriate Boiler and Pressure Vessel Inspection Authority.

4.5 Annex D includes some recommended mechanical and design details for information.

5 Proposals

5.1 Purchaser’s responsibilities

The purchaser's inquiry shall include specification sheets, a checklist if required, and other applicable information outlined in this International Standard (for example, in the formats given in annex A, annex B and annex C). All necessary data for the design of a heat exchanger unit shall be provided.

5.2 Vendor’s responsibilities

5.2.1 The vendor's proposal shall include, for each heat exchanger unit, completed specification sheets such as those given in annex A or, if a specification sheet is included in the inquiry, a statement indicating complete compliance with that specification sheet.

5.2.2 Designs that are not fully defined by the nomenclature in TEMA Standards, Section 1, shall be accompanied by sketches that are sufficient to describe the details of construction.

5.2.3 If distributor belts are provided, the vendor shall define the type of construction proposed.

5.2.4 The vendor shall determine the need for, and if required, include expansion joints based on all conditions supplied by the purchaser. The vendor shall state the type of construction proposed.

5.2.5 The proposal shall include a detailed description of all exceptions to the requirements of the purchaser's inquiry.

5.2.6 Unless otherwise specified, the vendor shall supply the complete heat exchanger unit including:

a) bolts, nuts and gaskets for the interconnecting nozzles of directly flanged stacked heat exchangers;

b) shims and bolting for interconnecting supports of heat exchangers.

5.2.7 Unless otherwise specified, the vendor shall provide a separate quotation for the following items:

a) a test component consisting of a test ring and gland, in accordance with TEMA Standard, Figure E-4.13-2 or equivalent, for each heat exchanger or group of similar heat exchangers with floating heads;

b) one spare set of gaskets per heat exchanger unit.

6 Drawings and other required data

6.1 Outline drawings

6.1.1 The vendor shall submit, for review by the purchaser, outline drawings for each heat exchanger unit. The drawings shall include the following information:

a) the service, item number, project name and location, purchaser's order number, vendor's shop order number, and other special identification numbers;

b) the design pressure, test pressure, design temperature, minimum design metal temperature, and any restriction on testing or operation of the heat exchanger;

c) the maximum allowable working pressure (MAWP) in the corroded condition and at the design temperature for the shell side and tube side;

d) the connection sizes, location, orientation, projection, direction of flow and, if flanged, the rating and facing;

e) the coupling sizes, rating and orientation;

f) the dimensions, orientation and location of supports, including bolt holes and slots, and the stacking arrangement;

g) the overall dimensions of the heat exchanger;

h) the tube bundle removal clearance;

i) the mass of the heat exchanger, empty and full of water, and of the tube bundle;

j) the specified corrosion allowance for each side of the heat exchanger;

k) references to the applicable code and the purchaser's specification;

l) requirements for postweld heat treatment;

m) requirements for radiographic examination;

n) requirements for material impact testing;

o) requirements for surface preparation and painting;

p) the gasket materials;

q) the insulation thickness;

r) the location of expansion joints, vapour distributors, and any other special components or closures;

s) the location and orientation of nameplates, lifting lugs, grounding clips or other attachments;

t) the location of the centre of gravity of the heat exchanger;

u) the forces and moments on connections as specified by the purchaser.

6.2 Information required after drawings are reviewed

6.2.1 Gasket details, including type and material, shall be shown on a separate drawing. This drawing shall not be marked with any restrictions for use.

● **6.2.2** Qualified welding procedure specifications and procedure qualification records as required by the pressure design code shall be submitted for review, if specified by the purchaser.

6.2.3 Upon receipt of the purchaser's review comments on the outline drawings, the vendor shall submit copies of all detailed drawings.

The detailed drawings shall fully describe the heat exchanger and shall include at least the following information:

a) full views and cross-sectional views with all dimensions and materials sufficient for stress calculations for each part;

b) bundle details, including the following:

   — tube layout;

   — tube description and number in each pass;

   — number of baffles, cross-baffle cut, layout and orientation in a view that shows the cuts;

   — details and locations of all sealing and sliding strips;

   — details and locations of tie-rods and spacers;

   — details and locations of support plates;

   — details of tubesheet and tube-holes, including cladding or weld overlay if required;

   — gasket drawings;

   — details of pass-partition plates.

c) details of each pressure-retaining weld, including weld material, weld nominal thickness, weld location and applicable non-destructive examination method;

d) details of each weld and weld nominal thickness for non-pressure attachments;

e) complete bills of materials, including the material specification;

f) expansion joint details;

g) details of cladding and weld overlay;

h) weld map for each heat exchanger showing the weld joints, including welding procedure number(s);

i) details of tube-to-tubesheet joints, including procedures for installation, welding, expansion, inspection and testing;

j) flange-face finish.

6.2.4 The vendor shall submit for the purchaser's review the following documentation (unless otherwise specified):

a) mechanical design calculations for all the heat exchanger pressure-retaining components. If calculations are made on a computer, all input and output data shall be detailed so as to facilitate an understanding of the calculation procedures; also, the formulas in the applicable sections of the pressure design code and the TEMA Standards shall be referenced;

b) design calculations based on seismic, transportation and/or piping loads, if these loads are provided by the purchaser;

c) proposed procedures for assembly of flanged joints, if controlled bolt-tightening procedures (such as hydraulic torque wrenches) are used. Any required lubricants shall be stated.

● **6.2.5** The vendor shall also submit design calculations for supports or lifting and pulling devices, and details of vibration analysis if specified by the purchaser.

6.2.6 After final review, the vendor shall revise all the required drawings and welding procedures, and submit each with the following text marked on every sheet separately and dated: “CERTIFIED FOR CONSTRUCTION”.

6.3 Reports and records

● After the heat exchanger is completed, the vendor shall furnish the purchaser with the specified number of copies of the following documents:

a) “as-built” specification sheet;

b) all outline and detail drawings, marked “CERTIFIED AS-BUILT”;

c) certified record of all impact tests performed;

d) certified mill test reports for all pressure parts, including tubes (each material test report shall be identified by a part number);

e) complete certified bill of materials suitable for obtaining all replacement parts, including quantity, description, material specification and identification of each part;

f) temperature charts of all postweld heat treatments;

g) a completed manufacturer's data report in accordance with the pressure design code;

h) nameplate rubbings or a facsimile;

i) all mechanical design calculations, marked “CERTIFIED AS-BUILT”;

j) a non-destructive examination map or procedure for each heat exchanger, showing the radiographic, magnetic-particle, liquid-penetrant, ultrasonic, hardness, impact and other applicable testing requirements;

k) tube-to-tubesheet leak-test results;

l) hydrostatic test records in the form of a chart or certification.

7 Design

7.1 Design temperature

● **7.1.1** All heat exchangers shall have two design temperatures for each side, a maximum design temperature and a minimum design metal temperature (MDMT), as specified by the purchaser (e.g. in the form shown in annex A).

7.1.2 For external bolting and for components exposed to both shell-side and tube-side fluids, the design temperature shall be the shell-side or tube-side design temperature, whichever is the more severe.

● **7.1.3** The input data needed to design an expansion joint shall be provided by the purchaser (e.g. in the form shown in annex A).

7.2 Cladding for corrosion allowance

7.2.1 If cladding (including weld overlay) is used, the full thickness of the cladding shall be used as corrosion allowance unless specified otherwise by the purchaser.

7.2.2 The thickness of bonded cladding shall be at least 2,5 mm (0,1 in). Weld overlay shall have sufficient thickness to provide the specified chemical composition to a depth of at least 1,6 mm (1/16 in).

7.3 Shell supports

7.3.1 The fixed shell support of removable-bundle heat exchangers shall be designed to withstand a longitudinal force equal to 150 % of the bundle mass applied at the heat exchanger bundle centreline. The shear stress for supports shall not exceed 40 % of the yield strength of the material.

7.3.2 Horizontal heat exchangers shall be provided with two or more saddles designed to support the heat exchanger units under all specified conditions. Design of the saddles shall be as follows:

a) Saddles shall be attached to saddle-bearing plates;

b) The bearing surface of the saddles shall be at least one-third of the circumference of the shell;

c) Saddle-bearing plates shall have the same nominal chemical composition as the shell and shall be continuously welded directly to the heat exchanger shells;

d) The saddle-bearing plates shall be provided with vent holes 6 mm (1/4 in) in diameter, located at the vertical centreline;

e) Saddle-bearing plates shall be at least 6 mm (1/4 in) thick and shall have all corners rounded to a radius of at least 25 mm (1 in).

7.3.3 The lower shells of stacked removable-bundle heat exchangers shall be designed to carry the superimposed load without suffering distortion that could cause binding of the tube bundles.

7.3.4 The vendor’s design shall provide for a shim allowance of approximately 6 mm (1/4 in) between the faces of stacked heat-exchanger intermediate supports.

7.3.5 For horizontal heat exchangers, slotted holes shall be provided in the baseplate of all but one of the saddles, to allow for longitudinal movement due to thermal expansion or contraction. The width of the slot shall be equal to the anchor bolt diameter plus 8 mm (5/16 in). The length of the slot shall be equal to the anchor bolt diameter, plus the allowance for longitudinal movement, plus 8 mm (5/16 in).

7.4 Stationary head

7.4.1 If a bonnet (see TEMA Standards, Figure N-1.2, Type B stationary head) is provided, the design of the heat exchanger shall permit full hydrostatic testing on the shell side with the bonnet removed.

7.4.2 Structural bracing shall not be used to retain pressure.

7.4.3 The pressure used to calculate the pass-partition plate thickness in accordance with TEMA Standards, RCB-9.132, shall be twice the clean calculated pressure drop across the pass-partition plate.

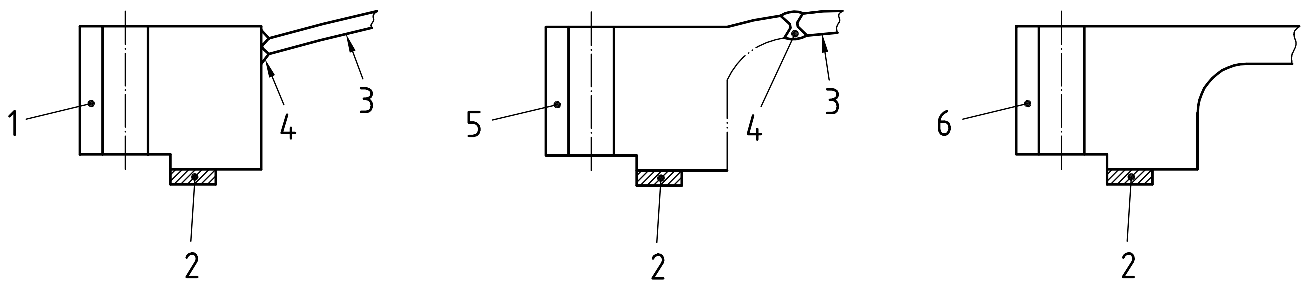
7.5 Floating head

7.5.1 Floating head cover bolting shall comply with TEMA Standards, Section 5, Paragraph RCB-11. Bolt spacings and clearances shall be not less than the minimum recommended by TEMA Standards.

7.5.2 Floating head cover bolting shall be readily accessible and shall have adequate spanner (wrench) clearance between the floating head bolts and the shell flange at the cover end when the shell cover is removed.

7.5.3 Packed floating head tailpipe and packed floating tubesheet designs, e.g. TEMA types P and W, shall not be used.

7.5.4 Unless otherwise agreed between the purchaser and the vendor, floating heads shall be designed for design pressure on either side, with atmospheric pressure or specified vacuum on the other side. Examples of acceptable floating head designs are shown in Figure 1.



a) Ring and dish construction **b) Flange and dish construction** **c) Integral construction**

Key

1 Ring
2 Gasket
3 Dish
4 Full-penetration weld
5 Flange
6 Integral machined cover

Figure 1 — Typical designs for floating head covers

7.5.5 Internal floating head covers shall have the specified corrosion allowance on all wetted surfaces except gasket seating surfaces. The specified corrosion allowance shall be included on the back side of the floating head backing device.

7.6 Tube bundle

7.6.1 Tubes

7.6.1.1 The minimum outside diameter of the tubes shall be 19,05 mm (3/4 in) unless otherwise specified by the purchaser.

7.6.1.2 Unless otherwise specified by the purchaser, the tube wall thickness shall be as listed in Table 1, or thicker if required by the design conditions.

Table 1 — Tube wall thickness

Dimensions in millimetres (inches)

Tube material	Wall thickness
Carbon steel, low-allow steel, aluminium and aluminium alloy	2,11 (0,083) minimum
Copper and copper alloys	1,65 (0,065) minimum
High-alloy steel and other non-ferrous materials	1,65 (0,065) average
Titanium	1,24 (0,049) average

7.6.1.3 The mean radius of U-bends shall be not less than 1,5 times the nominal outside diameter of the tube.

7.6.1.4 For low-fin tubing, the thickness at the root diameter shall be in accordance with 7.6.1.2.

7.6.2 Tubesheets

7.6.2.1 For a vertical heat exchanger unit where the stationary tubesheet is at the bottom, a suitable means of holding the bundle in place shall be provided. If collar bolts or drilled-and-tapped holes are used, at least four shall be provided and their location shall be identified.

7.6.2.2 The distance between the edge of the tube holes and the edge of all gasket grooves shall be not less than 1,6 mm (1/16 in) for tubesheets with expanded tube-to-tubesheet joints and not less than 3 mm (1/8 in) for tubesheets with seal-welded or strength-welded tube-to-tubesheet joints.

7.6.2.3 Unless otherwise agreed between purchaser and vendor, tubesheets shall be designed for design pressure on either side, with atmospheric pressure or specified vacuum on the other side.

7.6.2.4 If the tubesheet extends to the full diameter for bolting to an adjacent flange, the extended portion of the tubesheet outside the gasket shall be designed for the applied bolting moment. Both the gasket seating bolt load and the bolt-up load shall be in accordance with the pressure design code.

7.6.3 Transverse baffles and support plates

7.6.3.1 The thickness of ferritic transverse baffles and support plates shall be not less than twice the specified shell-side corrosion allowance.

7.6.3.2 Transverse baffles and support plates shall have notches that are 10 mm (3/8 in) high to facilitate drainage.

7.6.4 Impingement protection

7.6.4.1 If required by TEMA standards (RCB-4.61), impingement protection shall be provided by a plate baffle or rods on the tube bundle, a distributor belt, or another means agreed upon by the purchaser and the vendor.

7.6.4.2 If an impingement plate baffle is used, it shall extend at least 25 mm (1 in) beyond the projection of the nozzle bore.

7.6.4.3 If an impingement plate is used, the shell entrance and bundle entrance areas (as defined by TEMA Standards) shall be not less than the flow area of the inlet nozzle.

7.6.4.4 The nominal thickness of the impingement plate baffle shall be not less than 6 mm (1/4 in).

7.6.4.5 The impingement plate shall be adequately supported, e.g. by welding to at least two spacers, to avoid mechanical damage due to vibration.

7.6.4.6 Perforated impingement plates shall not be used.

7.6.5 Bypass sealing devices

7.6.5.1 Bypass sealing devices (such as seal bars, dummy tubes or tie-rods) as shown in Figure 2 shall be used for non-isothermal service if bypass clearances exceed 16 mm (5/8 in) and shall be located as follows:

a) if the distance between baffle-cut edges is six tube pitches or less, a single seal, located approximately halfway between the baffle cuts, shall be provided;

b) if the distance between baffle-cut edges exceeds six tube pitches, multiple seals shall be provided. A seal shall be located every five to seven tube pitches between the baffle cuts, with the outermost seals not more than 75 mm (3 in) from each baffle-cut edge.

7.6.5.2 Peripheral bypass seals shall extend from the peripheral edge of the transverse baffle into the tube bundle so that the clearance to the nearest tube does not exceed the nominal clearance between tubes.

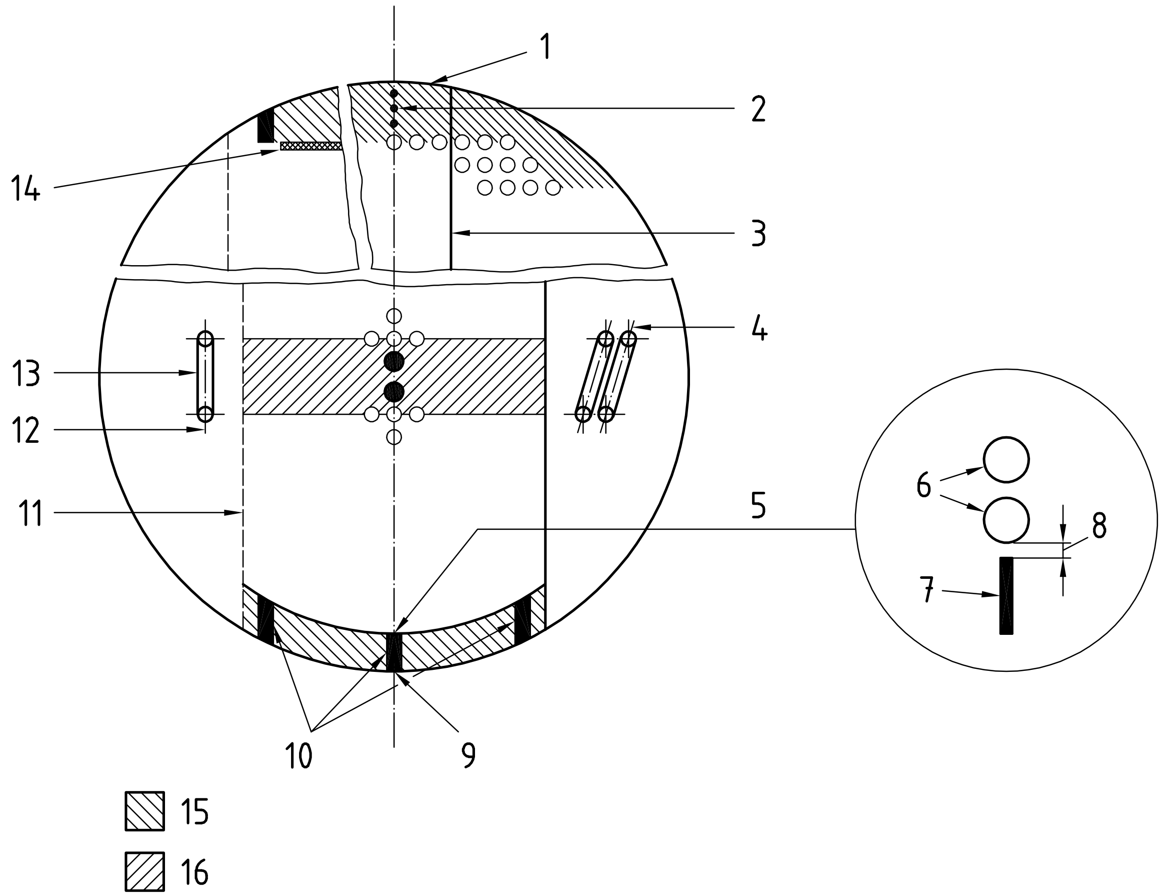
7.6.5.3 Internal bypass seals shall be installed so that the clearance to the nearest tube does not exceed the nominal clearance between tubes.

7.6.5.4 Bypass sealing devices shall either be located to minimize obstruction of mechanical cleaning lanes or shall be readily removable. Unless otherwise agreed, continous cleaning lanes shall be maintained for square (90°) and rotated-square (45°) pitch.

7.6.5.5 The nominal thickness of seal strips shall be the nominal thickness of the transverse baffles or 6 mm (1/4 in), whichever is less.

7.6.5.6 Bypass seal strips shall be attached to the transverse baffles by continuous welds on one side of each baffle.

7.6.5.7 Peripheral bypass seal strips shall not restrict the bundle inlet or outlet flows.



Key

1 Peripheral edge of baffle
2 Tie rods, dummy tubes or flat bar
3 Edge of baffle cut
4 Plane of U-tube bend
5 Detail of seals and tube clearance
6 Tubes
7 Seal
8 Clearance: not to exceed nominal tube clearance
9 Single seal on centreline
10 Multiple seals, evenly spaced
11 Edge of baffle cut
12 Plane of U-tube bend
13 U-tube bend
14 Impingement plate
15 Peripheral bundle bypass lane
16 Internal bundle bypass lane

Figure 2 — Typical cross-sections of tube bundle showing locations of bypass sealing devices

7.6.6 Bundle skid bars

7.6.6.1 For all removable bundles with a mass of more than 5 450 kg (12 000 lb), a continuous sliding surface shall be provided to facilitate bundle removal. If skid bars are used, they shall be welded to the transverse baffles and support plates to form a continuous sliding surface.

7.6.6.2 Skid bars shall protrude 0,8 mm (1/32 in) beyond the outside diameter of baffle and support plates.

7.6.6.3 The leading and trailing edges of skid bars and seal strips shall be provided with a radius or a bevel to prevent damage to the shell when inserting or removing the bundle.

7.6.7 Tube-to-tubesheet joint

Unless otherwise specified by the purchaser, the tube-to-tubesheet joint shall be expanded only. If welded joints are specified, the joint shall be welded by one of the following methods:

a) strength-welded only;

b) strength-welded and expanded;

c) seal-welded and expanded.

7.7 Nozzles and other connections

7.7.1 Connections DN 40 (NPS 1 1/2) and larger shall be flanged.

7.7.2 If welded connections are specified they shall be bevelled.

7.7.3 Non-flanged connections smaller than DN 40 (NPS 1 1/2) shall be forged couplings with an equivalent rating to ASME B 16.11 class 6000 or shall be integrally-reinforced welding fittings with tapered threads equivalent to ASME B 1.20.1, and shall comply with the pressure design code. Threaded connections shall not be used if hydrogen is present at a partial pressure exceeding 690 kPa (6,9 bar) (100 psi) absolute.

7.7.4 Flanged connections shall be of one of the following types:

a) forged or centrifugally-cast long welding neck (integrally flanged);

b) pipe welded to a forged or centrifugally-cast welding-neck flange;

c) pipe welded to a forged slip-on flange.

7.7.5 Slip-on flanges shall not be used under any of the following conditions:

a) if the pressure exceeds 2 070 kPa (20,7 bar) (300 psi) gauge;

b) if the design temperature exceeds 400 °C (750 °F);

c) if the corrosion allowance exceeds 3 mm (1/8 in);

d) if hydrogen is present at a partial pressure exceeding 690 kPa (6,9 bar) (100 psi) absolute;

e) in cyclic service, if the pressure design code requires fatigue analysis.

7.7.6 Flanges shall be in accordance with the pressure design code or other standard specified by the purchaser.

● **7.7.7** The projection of flanged connections shall allow through-bolting to be removed from either side of the flange without removing the insulation. The insulation thickness shall be specified by the purchaser.

7.7.8 Integrally reinforced nozzles shall be designed so that standard spanners (wrenches) fit the nuts without interference from nozzle neck reinforcement.

● **7.7.9** If chemical cleaning connections are specified by the purchaser, their nominal size shall be not less than DN 50 (NPS 2).

● **7.7.10** The design of connections shall be suitable to withstand the loads and moments specified by the purchaser.

7.8 Flanged external girth joints

7.8.1 Channel and shell external girth joints shall be of through-bolted construction.

7.8.2 Flanges for external girth joints shall be of the forged welding-neck type unless otherwise agreed by the purchaser.

7.8.3 Nubbins shall not be used unless approved by the purchaser; in which case, nubbins shall be located on the female (grooved) flange.

7.8.4 The nominal clearance between flanges after assembly shall be not less than 3 mm (1/8 in). The clearance between flanges shall extend within the bolt circle to allow flanges to be checked for radial distortion caused by an excessive bolt load.

7.8.5 Flanges shall be spot-faced or back-faced to the extent required by ASME B 16.5 or the pressure design code.

7.8.6 Hardened washers shall be provided under nuts for all bolts having diameters of 38 mm (1½ in) or larger. The washers shall be at least 6 mm (1/4 in) thick.

● **7.8.7** If bolt-tightening devices are specified by the purchaser, nozzles or girth flanges shall be designed to allow adequate clearance for their use.

7.9 Expansion joints

7.9.1 The vendor shall provide flush internal liners for thin-wall bellows-type expansion joints unless otherwise agreed by the purchaser. The liner material shall be compatible with the base material. Carbon steel liners shall be at least 6 mm (1/4 in) thick. Liners of stainless steel or other alloys shall be at least 3 mm (1/8 in) thick. For vertically mounted bellows, the liner shall be attached at the top and open at the bottom to allow for free drainage.

7.9.2 External protective covers shall be provided for thin-wall bellows-type expansion joints in the shell.

7.9.3 Internal floating head expansion joints shall have permanent stays to prevent damage during maintenance and hydrostatic testing with the shell cover removed. Stays shall be designed to permit the full movement of which the expansion bellows are capable.

7.9.4 Bellows-type expansion joints should be designed for at least 1 000 cycles during normal operation.

7.10 Gaskets

7.10.1 Gaskets in hydrocarbon service shall be double-jacketed fibre-filled metal, solid metal, serrated metal with soft gasket-seal facing, or spiral-wound fibre-filled metal.

7.10.2 A means shall be provided to prevent overcompression of spiral-wound gaskets.

7.10.3 Gaskets shall be of a one-piece design, unless otherwise specified by the purchaser.

7.11 Handling devices

7.11.1 The lifting device shall be a weld-on lug or ring provided with a hole not less than 38 mm (1½ in) in diameter. Wherever possible, the lug or ring shall be located at the top of the component, above its centre of gravity; otherwise, two suitably located lugs or rings shall be provided. The lifting device shall be designed to support at least twice the mass of the component.

7.11.2 For stacked heat exchangers, two lifting lugs or rings shall be provided on all covers, located at the top, approximately 45° from the vertical centreline.

7.11.3 Pulling lugs or tapped holes for the insertion of eyebolts shall be provided on the outer face of the stationary tubesheet to aid removal of the bundle from the shell. Pulling lugs and tapped holes shall be designed for a pulling force equal to at least 150 % of the bundle mass. Each tapped hole shall be fitted with a threaded plug of the same material as the tubesheet face. The exposed section of the plug shall be at least 50 mm (2 in) long.

7.11.4 All vertical heat exchangers shall be provided with lifting devices for the entire heat exchanger unit. The lifting devices shall be provided above the centre of gravity of the heat exchanger unit.

7.12 Hydrogen service

● If the purchaser specifies that the tube side and/or shell side will be exposed to hydrogen at a partial pressure exceeding 690 kPa (6,9 bar) (100 psi) absolute, totally enclosed spaces between welds shall be eliminated or vented with a hole of 6 mm (1/4 in) in diameter.

8 Materials

8.1 General

● **8.1.1** The purchaser shall specify if the service is sour in accordance with NACE MR0175 (i.e. sulfide stress cracking is possible), in which case all materials in contact with the process fluid shall meet the requirements of NACE MR0175.

8.1.2 Castings shall not be used unless approved by the purchaser.

8.1.3 Material for external parts that are welded directly to the heat exchanger, such as pads, brackets and lugs, shall be of the same nominal composition as the material to which they are welded.

● **8.1.4** If alloy linings are specified by the purchaser, they shall be weld overlay, integrally-clad or explosion-bonded. Loose liners or sleeves shall not be used without the approval of the purchaser.

8.2 Gaskets

8.2.1 Gaskets shall not contain asbestos.

8.2.2 Material for metal-jacketed, serrated-metal or solid-metal gaskets shall have a corrosion resistance at least equal to that of the gasket contact surface material.

8.2.3 Metal windings of spiral-wound gaskets shall be of austenitic stainless steel unless otherwise specified by the purchaser.

8.2.4 Serrated or solid-metal gaskets, including welds, shall be softer than the gasket contact surface.

8.2.5 Gasket material, including filler material, shall be selected to withstand the maximum design temperature.

8.3 Tubes

8.3.1 Integrally finned tubes of copper alloy shall be furnished in the annealed temper condition, such as ASTM B 359M.

8.3.2 All welded tubes shall be eddy-current tested in the finished condition over their full length.

9 Fabrication

9.1 Shells

9.1.1 All longitudinal and circumferential welds of shells for other than kettle-type heat exchanger units shall be finished flush with the inner contour for ease of tube-bundle insertion and withdrawal. For kettle-type heat exchanger units, this requirement shall not apply to welds in the enlarged section if they are not in the bottom quadrant of the shell.

9.1.2 For removable-bundle heat exchangers, the permissible out-of-roundness of a completed shell, after any required heat treatment, shall allow a metal template to pass through the entire shell length without binding. The template shall consist of two rigid disks (each with a diameter equal to the diameter of the transverse baffle or support plate) rigidly mounted perpendicularly on a shaft and spaced not less than 300 mm (12 in) apart.

9.1.3 Transverse baffle-to-shell clearances greater than those indicated in TEMA Standards, Table RCB-4.3, shall not be used unless approved by the purchaser.

9.2 Pass-partition plates

Pass-partition plates for forged or welded channels and floating heads shall be welded full length, either from both sides or with full-penetration welds, except for special designs approved by the purchaser. If welded from both sides, the first 50 mm (2 in) from the gasket face shall be full-penetration welds.

9.3 Connection junctions

Nozzles and couplings shall not protrude beyond the inside surface of the shell, channel or head to which they are attached.

9.4 Tubes

Each U-tube shall be formed from a single length and shall have no circumferential welds.

9.5 Welding

9.5.1 Welds may be made by any welding process other than oxyacetylene gas welding.

9.5.2 Category A and B welded joints shall be full-penetration welds and shall comply with the pressure design code.

9.5.3 All welds attaching connections to cylinders or to heads shall fully penetrate the total thickness of the component wall or the connection wall forming the attachment.

9.5.4 Where connections abut a component fabricated from plate (e.g. in the case of a set-on nozzle), the edge of the hole in the plate to which the connections are attached shall be examined for laminations by means of the magnetic-particle or liquid-penetrant method. Subject to agreement with the purchaser, indications found shall be cleared to sound metal and then repair-welded.

9.5.5 Backing strips that remain in place on the inside of a component after completion of welding shall not be used unless approved by the purchaser.

● **9.5.6** Tubes shall be welded to tubesheets if specified by the purchaser (e.g. for certain process conditions). The welding and testing procedures in these instances shall be mutually agreed upon by the purchaser and the vendor.

9.5.7 Welds attaching insulation support rings need not be continuous.

9.5.8 Welds attaching other non-pressure attachments (such as lugs or structural steel supports) shall be continuous.

9.5.9 Repair-associated welding procedures shall be submitted to the purchaser for review before the start of repair.

9.5.10 Full-penetration welds shall be used for those components that will be exposed to hydrogen at a partial pressure (absolute) exceeding 690 kPa (6,9 bar) (100 psi).

9.6 Heat treatment

9.6.1 Machined contact surfaces, including any threaded connections, shall be suitably protected to prevent scaling or loss of finish during heat treatment.

● **9.6.2** Requirements and procedures for heat treatment after bending for the bend portion of U-tubes shall be specified by the purchaser.

If the purchaser specifies heat treatment of U-bends of austenitic stainless steel, the procedure shall be as described in the pressure design code or shall be agreed between purchaser and vendor.

The U-bends of copper and copper alloy tubes, including copper-nickel alloys, shall be heat-treated as required by the pressure design code or shall be agreed between purchaser and vendor.

9.6.3 The heat-treated portion of the U-bend shall extend at least 150 mm (6 in) beyond the tangent point.

9.6.4 Postweld heat treatment of fabricated carbon steel channels and bonnets shall be performed for the following:

a) channels and bonnets with six or more tube passes;

b) two-pass and four-pass channels and bonnets whose cylinder-to-nozzle diameter ratios are 2,0 or less;

c) one-pass channels and bonnets whose nozzles are not axial and whose cylinder-to-nozzle diameter ratios are 2,0 or less.

● **9.6.5** Weld-overlaid carbon steel channels and bonnets shall be postweld heat treated if specified by the pressure design code or the purchaser.

9.6.6 Postweld heat treatment shall be performed for all carbon steel floating head covers that are fabricated by welding a dished-only head into a ring flange.

● **9.6.7** The purchaser shall specify if heat treatment is required for process reasons.

9.7 Dimensional tolerances

9.7.1 Manufacturing tolerances shall be such that nominally identical parts are interchangeable.

9.7.2 Heat exchangers that are to be stacked in service shall be stacked in the shop to check connection alignment.

9.7.3 For stacked heat exchangers, mating nozzle flanges shall not be out of parallel with each other by more than 0,8 mm (1/32 in), measured across any diameter. Separation of mating nozzle flanges shall not exceed 3 mm (1/8 in) after installation of the gasket. Bolts shall be capable of being inserted and removed freely without binding. Shims shall be installed as required between the supports and shall be tack-welded in place.

9.8 Gasket contact surfaces other than nozzle flange facings

9.8.1 Gasket contact surfaces shall have finishes as shown in Table 2.

Table 2 — Gasket contact surface finishes

Dimensions in micrometres (microinches)

Type	Surface roughness *Ra* [a]
Solid flat metal gaskets	1,6 (63) maximum
Double jacketed gaskets	1,6 to 3,2 (63 to 125)
Spiral wound gaskets	3,2 to 6,3 (125 to 250)
Serrated metal gaskets with soft gasket-seal facing	

[a] *Ra* is roughness average.

9.8.2 The flatness tolerance (maximum deviation from a plane) on peripheral gasket contact surfaces shall be 0,8 mm (1/32 in). The use of a straightedge to determine flatness tolerance is acceptable.

● **9.8.3** For special applications, such as high-pressure service, high-temperature service or hydrogen service, the following requirements shall be met if specified by the purchaser.

a) The flatness tolerances on peripheral gasket contact surfaces shall be as given in Table 3.

Table 3 — Flatness tolerance on peripheral gasket contact surfaces

Dimensions in millimetres (inches)

Heat exchanger nominal diameter	Tolerance
$<$ 375 (15)	$\pm$ 0,08 (0,003)
375 to 750 (15 to 30)	$\pm$ 0,15 (0,006)
751 to 1 125 (31 to 45)	$\pm$ 0,20 (0,008)
$>$ 1 125 (45)	$\pm$ 0,20 (0,008)

b) For heat exchangers without internal pass-partition covers, the flatness tolerance on individual pass-partition grooves shall be 0,8 mm (1/32 in).

9.8.4 Flange flatness tolerance and surface finish shall be measured after the flange has been attached to the component cylinder or the cover and after any postweld heat treatment.

9.8.5 The flatness of tubesheet gasket-contact surfaces shall be measured after the tube-to-tubesheet joints have been expanded or welded.

9.9 Tube-hole grooves

9.9.1 Tube-hole grooves shall be square-edged, concentric and free from burrs.

9.9.2 For shell-side-clad tubesheets, the tube shall be expanded to seal against the cladding material. In no case shall the rolling encroach within 3 mm (1/8 in) of the shell-side face of the tubesheet.

9.9.3 If austenitic stainless steel, duplex stainless steel, titanium, cupro-nickel, or nickel alloy tubes are specified, the tube holes shall be machined in accordance with TEMA Standards, Table RCB-7.41, column (b) (Special Close Fit).

9.10 Tube-to-tubesheet joints

9.10.1 If roller-expanded joints are utilized, the tube wall thickness reduction shall be in accordance with Table 4.

Table 4 — Allowable tube wall thickness reduction for roller-expanded tube-to-tubesheet joints

Material	Tube wall thickness reduction %
Carbon steel and low alloy steel	4 to 6 [a]
Stainless and high alloy steel	6 to 8 [a]
Non-ferrous	4 to 5 [a]

[a] The upper limit may be increased by a further 2 %, if approved by the purchaser.

9.10.2 If welded-and-expanded joints are specified, tube wall thickness reduction should begin at least 6 mm (1/4 in) away from welds.

9.11 Assembly

9.11.1 Match marks or dowels shall be provided to prevent misassembly of the following bolted joints:

a) floating head cover to tubesheet;

b) channel to tubesheet;

c) grooved channel cover to channel;

d) stationary tubesheet to shell.

9.11.2 The threads of external studs and nuts shall be coated with a suitable thread lubricant to prevent galling.

10 Inspection and testing

10.1 Quality assurance

● **10.1.1** If specified by the purchaser, materials, fabrication, conformance with mechanical design, and testing of heat exchangers shall be subject to inspection by the purchaser, a designated representative, or both.

10.1.2 The vendor shall notify the purchaser within an agreed timescale of the start of fabrication. The vendor shall also notify the purchaser of the date for bundle insertion, other required inspection points, and final inspection.

10.1.3 Unless otherwise specified, the inspector designated by the purchaser shall be permitted entry to the vendor's shop while the work is being performed. The vendor shall extend to the inspector the facilities and any reasonable opportunity to ensure that the heat exchanger is being furnished in accordance with the requirements specified by the purchase order.

10.1.4 No heat exchanger unit shall be released for shipment without the approval of the purchaser.

● **10.1.5** If inspection by the purchaser is specified (see 10.1.1), the purchaser shall specify the required degree of involvement, for example:

a) verification that qualified welding procedures and qualified welders and welding operators are being used by the manufacturer;

b) verification that the construction complies with the applicable drawings and with this International Standard;

c) review and/or examination of the results of any specified non-destructive examination;

d) witnessing of hydrostatic testing and any additional testing specified by the purchaser;

e) examination of required material certificates and the manufacturer's data reports.

10.1.6 No tubes or tube holes shall be plugged without notifying the purchaser. The method and procedure of plugging shall be subject to approval of the purchaser.

10.2 Quality control

10.2.1 As a minimum control, spot radiography shall be performed in accordance with the pressure design code, as follows:

a) At least one spot radiograph shall be made of each Category A and B welded joint. Nozzle welds are exempt from this requirement;

b) Spot radiographs shall include each start and stop of welds made by the automatic submerged-arc welding process;

c) Spot radiographs shall be a least 250 mm (10 in) long or shall be full length if the weld is less than 250 mm (10 in) long;

d) Weld porosity limits for spot radiographs shall be as stated in the pressure design code for fully radiographed joints.

10.2.2 The magnetic-particle examination method, extent and acceptance criteria shall comply with the pressure design code.

10.2.3 For non-magnetic materials, a liquid-penetrant examination shall be used in place of any required magnetic-particle examination.

10.2.4 The liquid-penetrant examination method and acceptance criteria shall comply with the pressure design code.

10.2.5 Weld hardness testing shall be in accordance with the pressure design code, or the following requirements, whichever is the more stringent:

a) The weld metal and heat-affected zone of pressure-retaining welds in components shall be tested;

b) Examination shall be made after any required postweld heat treatment;

c) Brinell hardness limits shall be in accordance with Table 5;

d) Hardness shall be determined using a 10 mm diameter ball unless otherwise specified;

e) One longitudinal weld, one circumferential weld, and each connection-to-component weld if the connection is DN 50 (NPS 2) or larger, shall be tested;

f) If more than one welding procedure is used to fabricate longitudinal or circumferential welds, hardness readings shall be made of welds deposited by each procedure.

Table 5 — Hardness limits

Material	Maximum Brinell hardness HBW
Carbon steel	225
Low alloy steel (0,5 % Cr max.)	225
Low alloy steel (0,5 % Cr to 2 % Cr)	225
Low alloy steel (2,25 % Cr to 10 % Cr)	240
High alloy martensitic steels	240
High alloy ferritic steels	240

10.2.6 For alloy-clad construction, both the stripped section of the base metal and the weld shall be examined by the magnetic-particle method prior to applying weld overlay.

10.2.7 All finished welds in ferromagnetic steel shall be examined after postweld heat treatment (unless the pressure design code specifies examination after hydrostatic testing) by the magnetic-particle method.

10.2.8 Final welds in all non-magnetic materials, whether of solid alloy or alloy-clad plate, shall be examined by the liquid-penetrant method after any required postweld heat treatment.

10.2.9 Final visual weld inspection shall be performed after postweld heat treatment.

10.2.10 After cladding, but prior to fabrication, integrally-clad material shall be subjected to an ultrasonic examination from the clad side in accordance with the pressure design code.

10.2.11 Overlay weldments, back-cladding and attachment welds to overlay weldments shall be liquid-penetrant examined after postweld heat treatment.

10.3 Pressure testing

10.3.1 In the case of welded-and-expanded tube-to-tubesheet joints, the tube weld integrity shall be verified before expanding the tubes by a pneumatic test from the shell side at a gauge pressure between 50 kPa (0,5 bar) (7,5 psi) and 100 kPa (1,0 bar) (15 psi), using a soap-water solution to reveal leaks.

10.3.2 Except for differential-pressure designs, an independent hydrostatic test of the shell-side and the tube-side shall be performed. The minimum fluid temperature for hydrostatic testing shall be as required by the pressure design code.

10.3.3 The hydrostatic test pressure shall be maintained for at least 1 h. After completion of the test, the heat exchanger shall be drained.

10.3.4 Heat exchangers in which austenitic stainless steel materials will be exposed to the test fluid shall be tested using potable water with a chloride ion content of less than 20 mg/kg (20 ppm by mass).

● **10.3.5** If specified by the purchaser, the shell-side hydrostatic test shall be conducted with the bonnet or channel cover removed.

10.3.6 Nozzle reinforcement pads shall be pneumatically tested at 170 kPa (1,7 bar) (25 psi) gauge.

10.3.7 For safety considerations, any supplementary pneumatic test shall be performed at a nominal pressure of 170 kPa (1,7 bar) (25 psi) gauge.

10.3.8 Flanged joints that have been taken apart after a hydrostatic test shall be reassembled with unused gaskets and re-hydrotested for tightness.

10.3.9 Paint or other external coatings shall not be applied over welds before the final hydrostatic test.

10.3.10 Heat exchangers that are stacked in service shall be hydrotested as a stacked heat exchanger unit.

10.4 Nameplates and stampings

10.4.1 A stainless steel nameplate shall be permanently attached to the heat exchanger in such a manner that it is visible after insulation has been installed.

10.4.2 The nameplate shall be located on the shell, near the channel end.

10.4.3 The following parts shall be stamped with the manufacturer's serial number:

a) shell flange;

b) shell cover flange;

c) channel or bonnet flange;

d) channel cover;

e) stationary tubesheet;

f) floating tubesheet;

g) floating head cover flange;

h) floating head backing device;

i) test ring flange and gland.

11 Preparation for shipment

11.1 Protection

11.1.1 All liquids used for cleaning or testing shall be drained from heat exchanger units before shipment.

11.1.2 Heat exchanger units shall be free of foreign matter prior to shipment.

11.1.3 All openings in heat exchanger units shall be suitably protected to prevent damage and possible entry of water or other foreign material.

11.1.4 All flange gasket surfaces shall be coated with an easily removable rust preventative and shall be protected by suitably attached durable covers of such material as wood, plastic or gasketed steel.

11.1.5 All threaded connections shall be protected by metal plugs or caps of compatible material.

11.1.6 Connections that are bevelled for welding shall be suitably covered to protect the bevel from damage.

● **11.1.7** The purchaser shall specify if there are additional requirements for surface preparation and protection (e.g. painting).

11.1.8 Exposed threads of bolts shall be protected with an easily removable rust preventative to prevent corrosion during testing, shipping and storage. Tapped holes shall be plugged with grease.

11.1.9 Tie-rods or tie-bars installed on shell expansion joints for protection during shipping shall be painted in a contrasting colour and clearly tagged to specify their removal before commissioning.

11.2 Identification

11.2.1 The item number, shipping mass and purchaser's order number shall be painted on the heat exchanger unit.

11.2.2 All boxes, crates or packages shall be identified with the purchaser's order number and the item number.

11.2.3 The words “DO NOT WELD” shall be stenciled (in at least two places 180° apart) on the side of equipment that has been postweld heat-treated.

12 Supplemental requirements

12.1 General

- Clause 12 includes additional requirements for design, fabrication and examination that apply to one or both sides of the heat exchanger if specified by the purchaser. In general, these supplemental requirements should be considered if the cylinder thickness of a heat exchanger component exceeds 50 mm (2 in) or if a heat exchanger is to be placed in a critical service. The purchaser shall specify if these supplemental requirements shall be applied.

12.2 Design

12.2.1 The attachment of welded nozzles and other connections to components shall have integral reinforcement. The nozzles or other connections shall be attached using full-penetration groove weld with additional fillet or butt welds. They may be set-on, set-in or integrally-reinforced forging type inserts. Set-on type connections shall not be welded to plate that contains laminations or other defects and shall only be used if the component is forged or if the component plates are ultrasonically examined in the area of attachment. In this case the examination for laminations and other defects shall be carried out for a radial distance of at least twice the thickness of the component.

12.2.2 Tubesheet attachment welds to shell or channel cylinders shall be butt welds.

12.3 Examination

12.3.1 All material for formed heads or cylinders exceeding 50 mm (2 in) in thickness shall be ultrasonically examined. Non-destructive examination and acceptance criteria shall comply with the pressure design code.

12.3.2 All forgings, except standard flanges designed as described in 7.7.6, shall be ultrasonically examined in accordance with the pressure design code. The criteria for acceptance shall be agreed upon by the purchaser and the vendor.

12.3.3 For ultrasonic examination of welds and forgings, the purchaser shall be supplied with a report providing diagrams of the surfaces scanned and indications obtained, the areas repaired, the nature of defects repaired, and the repair procedures used. The following information shall also be provided:

a) the pulse-echo instrument manufacturer's name and model and the damping control setting;

b) the search probe model, size and couplant type;

c) the frequency used and the test angle to the component surface;

d) the wedge medium for angle-beam examination.

12.3.4 Magnetic-particle examination shall be performed on all plate edges and openings before welding. Any defects found shall be removed and any necessary repairs performed.

12.3.5 Magnetic-particle examination shall be performed on all pressure-retaining welds. If accessible, the back side of the root pass shall be examined after being prepared for final welding. Both sides of accessible completed welds shall be examined.

12.3.6 Magnetic-particle examination shall be performed on all pressure-boundary attachment welds.

12.3.7 Magnetic-particle examination shall be performed on areas where temporary lugs have been removed. These areas shall be prepared by grinding them before the examination.

12.3.8 After the hydrostatic test, a magnetic-particle examination shall be performed on all external pressure-retaining welds and all internal nozzle welds that are accessible without disassembling the heat exchanger.

12.3.9 On components subject to full radiography, nozzle-attachment welds that cannot be radiographed shall be examined for the presence of cracks by the magnetic-particle method or by the liquid-penetrant method. Examination shall apply to the root pass after back-chipping or after flame-gouging, if applicable, and to the completed weld. Any defects revealed shall be removed before the weld is finished. For liquid-penetrant examination of austenitic stainless steel, neither the penetrant nor the developer shall contain any chlorides.

12.3.10 A full radiographic examination shall be performed on all pressure-retaining butt welds.

12.3.11 An ultrasonic examination shall be performed on all pressure-retaining butt welds after postweld heat treatment. Ultrasonic examination shall comply with the pressure design code. The entire volume of deposited weld metal shall be examined from two directions. Before the welds are examined, the adjacent base material shall be examined by means of longitudinal beam with a 100 % scan for a distance of twice the plate thickness back from the weld. A diagram shall be prepared indicating all areas larger than 12 mm (1/2 in) in diameter that show a loss of back-reflection of 50 % or more. The acceptance criteria shall be agreed upon by the purchaser and the vendor.

Annex A
(informative)

Specification sheet

A.1 General

The shell-and-tube heat exchanger specification sheet is an element of a complete shell-and-tube heat exchanger specification. This sheet provides preprinted line items to be completed by the purchaser and/or designer. Some sections of this sheet are optional and will not apply to some designs or may be omitted if agreed with the purchaser to comply with the preparer's established work process. It is also recognized that variations of the specification sheet format are in use within the industry. The format presented here is intended to provide a listing of typical information necessary for the exchanger design and a suggested format for presentation which may be used.

Each input item of the shell-and-tube heat exchanger specification sheet should be properly filled in or marked with "- -" to indicate that the information is not applicable. It is recommended that lines be left blank if the information is not known at the time. Lines not completed indicate the sheet is not complete and should be filled in by the designer or manufacturer.

Additional information that may be required, that does not have a preprinted description line, should be added in the "remarks" area of the specification sheet.

One or more pages may be required to define the shell-and-tube heat exchanger. Optional information may be:

— performance of one unit (page 1): This may be optional if the user or process licensor considers this information proprietary;

— connection schedule (page 2), materials of construction (page 2): gaskets (page 2): Used if the designer/user requires such level of detail to define materials for individual components. These sections may not be necessary if page one defines the information sufficiently;

— thermal expansion design exchanger design information (page 2): This is required only for exchangers such as fixed tubesheet or single-pass floating head type exchangers where thermal expansion must be considered for the mechanical design. An optional page 5 is included if operating information is supplied to the designer for determination of the metal temperatures necessary for expansion joint reviews;

— additional remarks, sketches, etc. (page 3): Used for additional remarks if sufficient space is not available on page 1. Also used for schematic sketches to illustrate required features of the design and tube layouts if necessary to provide this information to the manufacturer;

— page 4: This is a typical example of additional process information. One or two pages may be necessary if boiling and/or condensing fluids with ranges of physical properties occur;

— page 5: Design conditions which may be necessary for the designer to properly address the need for an expansion joint.

A.2 Specification sheet (SI units)

1	Client		Location		Page	1	of
2	Process unit		Item No.		Document No.		
3	Job No.		Fabricator				
4	Service of unit					No. of units	
5	Size	TEMA Type		Connected in:	Parallel		Series
6	Effective surface per unit	m^2	Shells/unit	Effective surface per shell			m^2
7	**PERFORMANCE OF ONE UNIT**						
8		**Inlet**	**SHELL SIDE**	**Outlet**	**Inlet**	**TUBE SIDE**	**Outlet**
9	Fluid name						
10	Fluid quantity, total	kg/h					
11	Vapour (relative molecular mass)	kg/h					
12	Liquid	kg/h					
13	Steam	kg/h					
14	Water	kg/h					
15	Non-condensable / relative molecular mass	kg/h					
16	Temperature	°C	/		/		
17	Density (vapour/liquid)	kg/m^3					
18	Viscosity (vapour/liquid)	mPa·s					
19	Specific heat (vapour/liquid)	kJ/(kg·K)					
20	Thermal conductivity (vapour/liquid)	W/(m·K)					
21	Specific latent heat	kJ/kg @ °C	@		@		
22	Inlet pressure	kPa (ga)					
23	Velocity	m/s					
24	Pressure drop (allowable/calculated)	kPa					
25	Fouling resistance	$m^2 \cdot K/W$					
26	Average film coefficient	$W/(m^2 \cdot K)$					
27	Heat exchanged	kW	Mean temp. diff., MTD (corrected) (weighted)				°C
28	Heat transfer rate (required/fouled/clean)	$W/(m^2 \cdot K)$					
29	ρV^2 [$kg/(m \cdot s^2)$]:	Inlet nozzle	Bundle entrance		Bundle exit		
30	**CONSTRUCTION PER SHELL**						
31	Tube No.	OD	mm	**NOZZLES – No., Size and Rating**			
32	Thickness	mm (min./average)			**SHELL SIDE**	**TUBE SIDE**	
33	Pitch	mm	Tube pattern	Inlet			
34	Length	m	Type	Outlet			
35	Tube-tubesheet joint			Intermediate			
36	Shell diameter (ID/OD)	/	mm	Vent			
37	Cross-baffle type			Drain			
38	Spacing: c/c	mm	No. of cross passes	Press. relief			
39	% Cut		Design pressure	kPa (ga)			
40	Tube support type		Vacuum	kPa (abs)			
41	Long baffle seal type		Design temp. (Max/MDMT)	°C	/	/	
42	Bypass seal type		No. of passes per shell				
43	Impingement Protection (Y/N)		Corrosion allowance	mm			
44	**MATERIALS OF CONSTRUCTION**						
45	Shell	Tubes		Gaskets:			
46	Shell cover			Shell side			
47	Channel or bonnet			Tube side			
48	Channel cover			Floating head			
49	Floating head cover/bolts			Spare sets req'd			
50	Tubesheet	Stat.	Floating	Test ring req'd (Y/N)			
51	Baffles:	Cross	Long	Insulation: shell			
52	Tube support material			Channel inlet/exit			
53	Expansion joint type			Expansion joint material			
54	Pressure design code	Stamp		Calc. MAWP (Y/N)		TEMA Class	
55	REMARKS:						
56							
57							
58							
59	Originator/Check:	/	Approved	Issue date:		Issue No.	

Job No.		Page 2 of	
Client			
Location			
Item No.			
Document No.		Issue No.	

CONNECTION SCHEDULE (Optional)					
Mark	No. req'd	Size	Rating	Facing	Description

THERMAL EXPANSION DESIGN INFORMATION (Optional)					
	Shell mean metal Temp. °C	Shell press. kPa (ga)	Tubesheet mean metal Temp. °C	Tube mean metal Temp. °C	Tube press. kPa(ga)
Design					
Normal					
Starting					
Shutdown					
Upset #1					
Upset #2					
Steam out					
Expansion joint design life cycles					

MATERIALS OF CONSTRUCTION (Optional)	Corr. allow.
Shell:	mm
Head:	mm
Pipe/stub ends:	mm
Nozzle necks:	mm
Nozzle flanges:	mm
Body flanges:	mm
Expansion joint:	mm
Support	mm
Bolting (internal):	mm
Bolting (external):	mm
Nozzle reinforcement:	mm
Tubes:	mm
Tubesheets:	mm
Bonnet/channel:	mm
Bonnet head(s)	mm
Channel cover(s):	mm
Body flanges:	mm
Pipe/stub ends:	mm
Bolting (internal):	mm
Bolting (external):	mm
Nozzle reinforcement	mm
Nozzle necks:	mm
Nozzle flanges:	mm
Baffles, spacers, tie rods:	mm

GASKETS (Optional)					
Shell side:	Thickness:		mm		
	y =	Pa	m =		
Tube side:	Thickness:		mm		
	y =	Pa	m =		
Floating head	Thickness:		mm		
	y =	Pa	m =		

MECHANICAL DATA (Optional)				
MAWP (hot and corroded):			kPa (ga)	
MAP (new and cold):			kPa (ga)	
Hydrotest pressure:				
	Field:	kPa (ga)	Shop:	kPa (ga)
Masses:	Empty:	kg	Bundle:	kg
	Full of water:	kg		

Job No.	Page	3	of
Client			
Location			
Item No.			
Document No.	Issue No.		

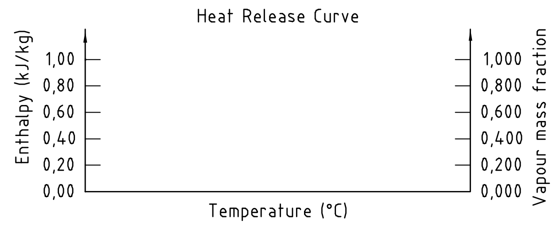
ADDITIONAL REMARKS, SKETCHES, ETC. (Optional)

Job No.	Page 4 of
Client	
Location	
Item No.	
Document No.	Issue No.

•

Fluid Name: Ref. Pressure 1: bar (abs)

Pressure bar (abs)	Temp °C	Enthalpy kJ/kg	Vapour Mass Fraction

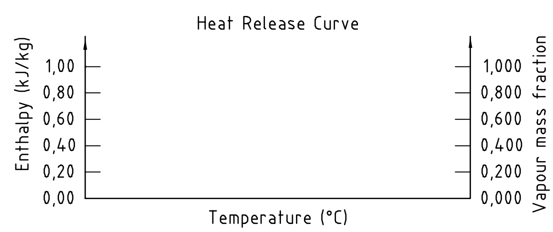


Enthalpy (kJ/kg) Vapour mass fraction

Density Vapour	Density Liquid	Viscosity Vapour	Viscosity Liquid	Thermal Cond. Vap	Thermal Cond. Liq	Sp. Heat Vapour	Sp. Heat Liquid	Surface Tension	Liquid Critical Press.	Liq Crit Temp.
kg/m^3	kg/m^3	mPa·s	mPa·s	W/m·K	W/m·K	kJ/(kg·K)	kJ/(kg·K)	N/m	bar (abs)	°C

Fluid Name: Ref. Pressure 2: bar (abs)

Pressure bar (abs)	Temp °C	Enthalpy kJ/kg	Vapour Mass Fraction



Enthalpy (kJ/kg) Vapour mass fraction

Density Vapour	Density Liquid	Viscosity Vapour	Viscosity Liquid	Thermal Cond. Vap	Thermal Cond. Liq	Sp. Heat Vapour	Sp. Heat Liquid	Surface Tension	Liquid Critical Press.	Liq Crit Temp.
kg/m^3	kg/m^3	mPa·s	mPa·s	W/m·K	W/m·K	kJ/(kg·K)	kJ/(kg·K)	N/m	bar (abs)	°C

Job No.	Page 5 of
Client	
Location	
Item No.	
Document No.	Issue No.

DESIGN CONDITIONS FOR EXPANSION JOINT (Optional)

Case [a]	SHELL SIDE					TUBE SIDE				
	Flow condition [b]	Fluid temperature		Pressure [d]	Mean metal temperature [e]	Flow condition [b]	Fluid temperature		Pressure [d]	Mean metal temperature [e]
		Inlet	Outlet [c]				Inlet	Outlet [c]		
		°C	°C	kPa (ga)	°C		°C	°C	kPa (ga)	°C

Determine the mean shell and tube metal temperatures at the following operating conditions. Evaluate the need for an expansion joint based on the metal temperatures at these conditions with either or both sides clean or with specified fouling.

Unless otherwise specified, operation in accordance with the recommendations of the TEMA Standards, paragraph E3.2, “Operating Procedures”, is assumed.

[a] Case = e.g. steam out, upset, etc., which may affect design.

[b] F = Flowing (specify flowrate), S = Stagnant, E = Empty.

[c] Outlet temperature = (if known), thermal designer determines for other conditions.

[d] Pressure = Specify design pressure for operating conditions. Use maximum actual pressure at other conditions.

[e] Mean metal temperature = To be provided by the thermal designer.

A.3 Specification sheet (US Customary units)

1	Client	Location	Page	1	of
2	Process unit	Item No.	Document No.		
3	Job No.	Fabricator			

4	Service of unit					No. of units
5	Size	TEMA Type		Connected in:	Parallel	Series
6	Effective surface per unit	ft²	Shells/unit	Effective surface per shell		ft²
7	**PERFORMANCE OF ONE UNIT**					

8			**Inlet**	**SHELL SIDE**	**Outlet**	**Inlet**	**TUBE SIDE**	**Outlet**
9	Fluid name							
10	Fluid quantity, total	lb/h						
11	Vapour (relative molecular mass)	lb/h						
12	Liquid	lb/h						
13	Steam	lb/h						
14	Water	lb/h						
15	Noncondensable / relative molecular mass	lb/h		/			/	
16	Temperature	°F						
17	Density (vapour/liquid)	lb/ft³						
18	Viscosity (vapour/liquid)	cP						
19	Specific heat (vapour/liquid)	Btu/(lb·°F)						
20	Thermal conductivity (vapour/liquid)	Btu/(h·ft·°F)						
21	Specific latent heat	Btu/lb @ °F		@			@	
22	Inlet pressure	psig						
23	Velocity	ft/s						
24	Pressure drop (allowable/calculated)	psi						
25	Fouling resistance	h·ft²·°F/Btu						
26	Average film coefficient	Btu/(h·ft²·°F)						
27	Heat exchanged	Btu/h	Mean temp. diff., MTD (corrected) (weighted)					°F
28	Heat transfer rate (required/fouled/clean)	Btu/(h·ft²·°F)						
29	ρV^2 [lb/(ft·s²)]: Inlet nozzle		Bundle entrance			Bundle exit		
30	**CONSTRUCTION PER SHELL**							

31	Tube No.	OD	in	**NOZZLES – No., Size and Rating**		
32	Thickness	in/BWG (min./average)			**SHELL SIDE**	**TUBE SIDE**
33	Pitch	in	Tube pattern	Inlet		
34	Length	ft	Type	Outlet		
35	Tube-tubesheet joint			Intermediate		
36	Shell diameter (ID/OD)	/	in	Vent		
37	Cross-baffle type			Drain		
38	Spacing: c/c	in	No. of crosspasses	Pressure relief		
39	% Cut		Design pressure	psig		
40	Tube support type		Vacuum pressure	psia		
41	Long baffle seal type		Design temp. (Max/MDMT)	°F	/	/
42	Bypass seal type		No. of passes per shell			
43	Impingement protection (Y/N)		Corrosion allowance	in		
44	**MATERIALS OF CONSTRUCTION**					

45	Shell		Tubes	Gaskets:	
46	Shell cover			Shell side	
47	Channel or bonnet			Tube side	
48	Channel cover			Floating head	
49	Floating head cover/bolts			Spare sets req'd	
50	Tubesheet	Stat.	Floating	Test ring req'd (Y/N)	
51	Baffles:	Cross	Long	Insulation: shell	
52	Tube support material			Channel inlet/exit	
53	Expansion joint type			Expansion joint material	
54	Pressure design code		Stamp	Calc. MAWP (Y/N)	TEMA Class
55	REMARKS :				
56					
57					
58					
59	Originator/check:	/	Approved	Issue date:	Issue No.

Job No.	Page 2 of	
Client		
Location		
Item No.		
Document No.	Issue No.	

CONNECTION SCHEDULE (Optional)

Mark	No. req'd	Size	Rating	Facing	Description

THERMAL EXPANSION DESIGN INFORMATION (Optional)

	Shell mean metal temp. °F	Shell press. psig	Tubesheet mean metal temp. °F	Tube mean metal temp. °F	Tube press. psig
Design					
Normal					
Starting					
Shutdown					
Upset #1					
Upset #2					
Steam out					
Expansion joint design life cycles					

MATERIALS OF CONSTRUCTION (Optional)	Corr. allow.
Shell:	in
Head:	in
Pipe/stub ends:	in
Nozzle necks:	in
Nozzle flanges:	in
Body flanges:	in
Expansion joint:	in
Support	in
Bolting (internal):	in
Bolting (external):	in
Nozzle reinforcement:	in
Tubes:	in
Tubesheets:	in
Bonnet/channel:	in
Bonnet head(s)	in
Channel cover(s):	in
Body flanges:	in
Pipe/stub ends:	in
Bolting (internal):	in
Bolting (external):	in
Nozzle reinforcement	in
Nozzle necks:	in
Nozzle flanges:	in
Baffles, spacers, tie rods:	in

GASKETS (Optional)

Shell side:	Thickness:				in
	y =	psi	*m* =		
Tube side:	Thickness:				in
	y =	psi	*m* =		
Floating head	Thickness:				in
	y =	psi	*m* =		

MECHANICAL DATA (Optional)

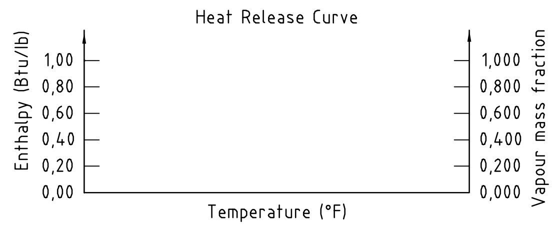
MAWP (hot and corroded):		psi		
MAP (new and cold):		psi		
Hydrotest pressure:				
	Field:	psig	Shop:	psig
Masses:	Empty:	lb	Bundle:	lb
	Full of water:	lb		

Job No.	Page	3	of
Client			
Location			
Item No.			
Document No.	Issue No.		

ADDITIONAL REMARKS, SKETCHES, ETC. (Optional)

Job No.	Page	4	of
Client			
Location			
Item No.			
Document No.	Issue No.		

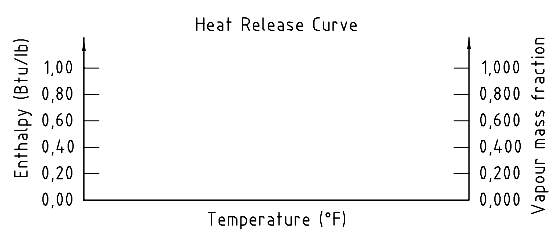
Fluid Name	Ref. Pressure 1:	psi (abs)	
Pressure psi (abs)	Temp °F	Enthalpy Btu/lb	Vapour Mass Fraction



Enthalpy (Btu/lb) Vapour mass fraction

Density Vapour	Density Liquid	Viscosity Vapour	Viscosity Liquid	Thermal Cond. Vap	Thermal Cond. Liq	Sp. Heat Vapour	Sp. Heat Liquid	Surface Tension	Liquid Critical Press.	Liq. Crit Temp.
lb/ft^3	lb/ft^3	cP	cP	Btu/(hr·ft·°F)	Btu/(hr·ft·°F)	Btu/(lb·°F)	Btu/(lb·°F)	dyne/cm	psia	°F

Fluid Name	Ref. Pressure 2:	psi (abs)	
Pressure psi (abs)	Temp °F	Enthalpy Btu/lb	Vapour Mass Fraction



Enthalpy (Btu/lb) Vapour mass fraction

Density Vapour	Density Liquid	Viscosity Vapour	Viscosity Liquid	Thermal Cond. Vap	Thermal Cond. Liq	Sp. Heat Vapour	Sp. Heat Liquid	Surface Tension	Liquid Critical Press.	Liq. Crit Temp.
lb/ft^3	lb/ft^3	cP	cP	Btu/(hr·ft·°F)	Btu/(hr·ft·°F)	Btu/(lb·°F)	Btu/(lb·°F)	dyne/cm	psia	°F

Job No.	Page	5	of
Client			
Location			
Item No.			
Document No.	Issue No.		

DESIGN CONDITIONS FOR EXPANSION JOINT (Optional)

Case [a]	SHELL SIDE					TUBE SIDE				
	Flow condition [b]	Fluid temperature		Pressure [d]	Mean metal temperature [e]	Flow condition [b]	Fluid temperature		Pressure [d]	Mean metal temperature [e]
		Inlet	Outlet [c]				Inlet	Outlet [c]		
		°F	°F	psig	°F		°F	°F	psig	°F

Determine the mean shell and tube metal temperatures at the following operating conditions. Evaluate the need for an expansion joint based on the metal temperatures at these conditions with either or both sides clean or with specified fouling.

Unless otherwise specified, operation in accordance with the recommendations of the TEMA Standards, paragraph E3.2, “Operating Procedures”, is assumed.

[a] Case = e.g. steam out, upset, etc., which may affect design.

[b] F = Flowing (specify flow rate), S = Stagnant, E = Empty.

[c] Outlet temperature = (if known), thermal designer determines for other conditions.

[d] Pressure = Specify design pressure for operating conditions. Use maximum actual pressure at other conditions.

[e] Mean metal temperature = To be provided by the thermal designer.

Annex B
(informative)

Shell-and-tube heat exchanger checklist

This checklist summarizes the bulleted subclauses in this International Standard, i.e. the subclauses in which a decision is required by the purchaser.

Subclause	Item	Requirement	
4.1	Pressure design code to be used?		
4.3	Applicable local regulations:		
6.2.2	Welding procedures and qualifications to be submitted for review?	Yes	No
6.2.5	Design calculations for lifting/pulling devices to be submitted for review?	Yes	No
	Vibration analysis to be submitted for review?	Yes	No
6.3	Number of copies of reports and records required:		
7.1.1	Maximum design temperature: (annex A, line 41)		
	Minimum design metal temperature (MDMT): (annex A, line 41)		
7.1.3	Expansion joint conditions: (annex A)		
7.7.7	Insulation thickness		
	Shell:		
	Channel:		
7.7.9	Chemical cleaning connections required?	Yes	No
7.7.10	Loads and moments on connections?		
7.8.7	Bolt tightening devices required?	Yes	No
7.12	Is heat exchanger exposed to hydrogen at partial pressure exceeding 690 kPa (6,9 bar) (100 psi) absolute?	Yes	No
	Which side of heat exchanger is in hydrogen service?		
	Shell side	Yes	No
	Tube side	Yes	No
8.1.1	Sour service (as defined by NACE MR0175)?	Yes	No
8.1.4	Alloy linings?	Yes	No

Subclause	Item	Requirement	
9.5.6	Welded tube-to-tubesheet joints required?	Yes	No
9.6.2	Heat treatment requirements and procedures for U-tube bend sections:		
9.6.5	Postweld heat treatment of weld-overlaid carbon steel channels and bonnets?	Yes	No
9.6.7	Postweld heat treatment for process reasons?		
	Shell side	Yes	No
	Tube side	Yes	No
9.8.3	Special flatness tolerance on gasket contact surfaces?	Yes	No
10.1.1	Purchaser's inspection?	Yes	No
10.1.5	Extent of purchaser's inspection:		
10.1.5 d)	Additional testing:		
10.3.5	Removal of bonnet or channel cover for shell-side hydrostatic test?	Yes	No
11.1.7	Additional painting requirements:	Yes	No
	Details:		
12.1	Supplemental requirements apply to:		
	Shell side	Yes	No
	Tube side	Yes	No
	Details:		

Annex C
(informative)

Responsibility specification sheet

1	Client	P	Location	P	Page	1	of		
2	Process unit	P	Item No.	P	Document No.	P			
3	Job No.	P	Fabricator	P					
4	Service of unit	P	No. of units: P						
5	Size	D	TEMA Type	P	Connected in	D	Parallel	D	Series
6	Surface/unit (eff.)	D	Shells/unit	D	Surface/shell (eff.)	D			
7	**PERFORMANCE OF ONE UNIT**								
8	Fluid allocation	**(Inlet)**	**SHELL SIDE**		**(Outlet)**	**(Inlet)**	**TUBE SIDE**		**(Outlet)**
9	Fluid name	P				P			
10	Fluid quantity, total	P				P			
11	Vapour (relative molecular mass)	P	P	P	P	P	P	P	P
12	Liquid	P		P		P		P	
13	Steam	P		P		P		P	
14	Water	P		P		P		P	
15	Noncondensable / relative molecular mass	P / P				P / P			
16	Temperature	P		P		P		P	
17	Density (vapour/liquid)	P	P	P	P	P	P	P	P
18	Viscosity (vapour/liquid)	P	P	P	P	P	P	P	P
19	Specific heat (vapour/liquid)	P	P	P	P	P	P	P	P
20	Thermal conductivity (vapour/liquid)	P	P	P	P	P	P	P	P
21	Latent heat	P @ P				P @ P			
22	Inlet pressure	P				P			
23	Velocity	D				D			
24	Pressure drop (allowable/calculated)	P		D		P		D	
25	Fouling resistance	P				P			
26	Average film coefficient	D				D			
27	Heat exchanged	P	MTD (corrected) (weighted)	D					
28	Transfer rate (required/fouled/clean)	D	D	D					
29	ρV^2	Inlet nozzle	D	Bundle entrance	D	Bundle exit	D		

30	**CONSTRUCTION PER SHELL**						
31	Tube No.	D	OD	P	**NOZZLES – No., Size and Rating**		
32	Thickness	P	(Min./Avg).	P		**SHELL SIDE**	**TUBE SIDE**
33	Pitch	P	Tube pattern	P	Inlet	P	P
34	Length	P	Type	P	Outlet	P	P
35	Tube-tubesheet joint	P			Intermediate	D	D
36	Shell diameter (ID/OD)	D	/	D	Vent	P	P
37	Cross baffle type			D	Drain	P	P
38	Spacing:	D	No. of crosspasses	D			
39	% Cut	D			Design pressure	P	P
40	Tube support type	D			Vacuum pressure	P	P
41	Long baffle seal type	D			Design temp. (Max./MDMT)	P / P	P / P
42	Bypass seal type	D			No. of passes per shell	D	D
43	Impingement Protection (Y/N)	D			Corrosion Allowance	P	P
44	**MATERIALS OF CONSTRUCTION**						
45	Shell	P	**Tubes**	P	Gaskets:		
46	Shell cover		P		Shell side	P	
47	Channel or bonnet		P		Tube side	P	
48	Channel cover		P		Floating head	P	
49	Floating head cover/bolts		P		Spare sets req'd	P	
50	Tubesheet	Stat. P	Floating	P	Test ring req'd (Y/N)	P	
51	Baffles:	Cross P	Long	P	Insulation: shell	P	
52	Tube support material		P		Channel inlet/exit	P	
53	Expansion joint type		P		Expansion joint material	P, D	
54	Pressure design code	P	Stamp	P	Calc. MAWP (Y/N)	P	TEMA Class P
55	REMARKS :	P, D					
56			**P = Purchaser**				
57			**D = Designer**				
58							
59	Originator/check:	/	Approved		Issue Date:	Issue No.	

Annex D
(informative)

Recommended practices

D.1 Introduction

This annex has been prepared to give advice to the designer in areas outside the scope of the basic standard. The advice is not mandatory and is offered for guidance only.

The numbers in brackets refer to the clause/subclause numbers of the main text of this International Standard.

D.2 Design

D.2.1 Tube failure in high pressure units (clause 7)

If a unit is subject to a large operating pressure differential between the shell side and the tube side, the effect of tube failure should be considered.

NOTE For further information see references [4] and [5].

D.2.2 Tube bundle and tubes (7.6.1)

D.2.2.1 For U-tube type bundles, if the mean bend radius is less than three times the tube outside diameter, the tube wall thickness should be increased to compensate for thinning in the bends. Such thinning can be as much as 17 %.

D.2.2.2 In calculating the effective surface, the purchaser and vendor should agree as to whether the “U” bend region should be included.

D.2.3 Transverse baffles and support plates (7.6.3)

Segmental baffles are conventional in shell-and-tube heat exchangers, as described in 7.6.3. Other designs such as rod-baffles, helical baffles and twisted tube designs may be permitted if agreed with the purchaser.

D.2.4 Tube bundle skid bars (7.6.6)

D.2.4.1 For bundles with mass and dimensions outside the range of conventional bundle-pulling devices, alternative means of bundle removal should be considered. For example, if the bundle mass exceeds 18 150 kg (40 000 lb), the diameter exceeds 1 220 mm (48 in), or the length exceeds 7,3 m (24 ft), the following options may be considered:

a) bundle rollers;

b) skid bars on a rail;

c) removable shell.

D.2.4.2 Skid bars should not obstruct tube lanes or pass-partition lanes if 45° or 90° tube layouts are used.

D.2.5 Tube-to-tubesheet joints (7.6.7)

D.2.5.1 To minimize crevice corrosion on the shell side, tubes should be contact-expanded into the tubesheet for a length of tubesheet thickness minus 3 mm (1/8 in).

D.2.5.2 For heat exchangers operating at a pressure above 7 000 kPa (70 bar) (1 000 psi) gauge, tube-to-tubesheet joints should be strength-welded. In addition, expansion of the tubes should be considered.

D.2.5.3 For heat exchangers in hydrogen service, tube-to-tubesheet joints should be strength-welded and expanded.

D.2.6 Bellows-type expansion joints (7.9.4)

D.2.6.1 If extreme conditions (e.g. upset conditions) may be expected, bellows-type expansion joints should be designed for a minimum of 100 cycles. This is in addition to the elongation or compressive values for the minimum 1 000 cycles of normal operation.

D.2.6.2 Bellows should be formed from a cylinder having only longitudinal seams. The longitudinal weld seam should be examined using liquid penetrant after manufacture.

D.2.6.3 All expansion bellows welds, including attachment welds, should be 100 % examined by the liquid-penetrant method. The acceptance criteria should comply with the pressure design code.

D.3 Fabrication

D.3.1 Shell (9.1)

Openings and attachments (including reinforcing pads and support pads) should clear weld seams by at least 50 mm (2 in). If this construction is not possible, the seam weld should be ground flush and radiographed for a distance of 100 mm (4 in) on either side of the opening or for the full length covered by an attachment plus 100 mm (4 in) on either side prior to welding the nozzle or attachment to the heat exchanger.

D.3.2 Tube-to-tubesheet joint (9.10)

D.3.2.1 For welded-and-expanded tube-to-tubesheet joints of low alloy steel requiring postweld heat treatment, the tubes should be expanded after postweld heat treatment.

D.3.2.2 If welded tube-to-tubesheet joints are specified for dissimilar tubes and tubesheet material, a 3 mm (1/8 in) minimum weld overlay or cladding should be provided on the tubesheet to eliminate bimetallic welds. The overlay or cladding should have the same metallurgy as the tubes.

D.3.2.3 If using titanium, tube-to-tubesheet joints should be seal-welded and expanded.

D.4 Preparation for shipment protection (11.1.1)

D.4.1 If water residues cannot be tolerated, equipment should be dried by one of the following methods:

a) blowing dry air or nitrogen, of relative humidity less than 15 % (usually dehumidified), through the heat exchanger and monitoring the outlet air until the relative humidity falls below 30 %;

b) evacuating the heat exchanger with a vacuum pump to an absolute pressure of between 0,4 kPa and 0,5 kPa.

D.4.2 After draining and drying, internal surfaces may be protected against corrosion by the addition of a dessicant, e.g. silica gel, by the addition of a volatile corrosion inhibitor, or by blanketing with an inert gas such as nitrogen [typically at gauge pressures up to 100 kPa (1 bar) (15 psi)].

Bibliography

[1] API Standard 660, February 2001, *Shell-and-tube heat exchangers for general refinery services,* 6th edition

[2] ASME Boiler and Pressure Vessel Code, Section VIII, *Rules for construction of pressure vessels*

[3] ASTM B 359M, *Standard specification for copper and copper-alloy seamless condenser and heat exchanger tubes with integral fins (metric)*

[4] API RP 521, March 1997, *Guide for pressure-relieving and depressuring systems,* 4th edition

[5] The Institute of Petroleum[4)], *Guidelines for the design and safe operation of shell-and-tube heat exchangers to withstand the impact of tube failure*

4) The Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR, United Kingdom.

2003 Publications Order Form

API

Effective January 1, 2003.
API Members receive a 50% discount where applicable.
The member discount does not apply to purchases made for the purpose of resale.

Available through Global Engineering Documents:
Phone Orders: **1-800-854-7179** (Toll-free in the U.S. and Canada)
303-397-7956 (Local and International)
Fax Orders: **303-397-2740**
Online Orders: **www.global.ihs.com**

Date: ______________________ ❑ **API Member** (Check if Yes)

Invoice To (❑ Check here if same as "Ship To")
Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
E-Mail:

Ship To (UPS will not deliver to a P.O. Box)
Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
E-Mail:

Quantity	Product Number	Title	SO★	Unit Price	Total
	CX53005	API Std 530/ISO 13704, *Calculation of Heater Tube Thickness in Petroleum Refineries/Petroleum and natural gas industries—Calculation of heater tube thickness in petroleum refineries*		$ 150.00	
	C56003	API Std 560, *Fired Heaters for General Refinery Services*		$ 160.00	
	CX66105	ANSI/API Std 661/ISO 13706, *Air-cooled Heat Exchangers for General Refinery Services/Petroleum and natural gas industries—Air-cooled heat exchangers*		$ 119.00	
	CX66202	ANSI/API Std 662/ISO 15547, *Plate Heat Exchangers for General Refinery Services/Petroleum and natural gas industries—Plate heat exchangers*		$ 75.00	

Subtotal	
Applicable Sales Tax *(see below)*	
Rush Shipping Fee *(see below)*	
Shipping and Handling *(see below)*	
Total *(in U.S. Dollars)*	

❑ **Payment Enclosed** ❑ **P.O. No.** (Enclose Copy) ____________

❑ **Charge My Global Account No.** ____________

❑ **VISA** ❑ **MasterCard** ❑ **American Express** ❑ **Diners Club** ❑ **Discover**

Credit Card No.:
Print Name (As It Appears on Card):
Expiration Date:
Signature:

★ ***To be placed on Standing Order for future editions of this publication, place a check mark in the SO column and sign here:***

Pricing and availability subject to change without notice.

Mail Orders – Payment by check or money order in U.S. dollars is required except for established accounts. State and local taxes, $10 processing fee*, and 5% shipping must be added. Send mail orders to: **API Publications, Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776, USA.**
Purchase Orders – Purchase orders are accepted from established accounts. Invoice will include actual freight cost, a $10 processing fee*, plus state and local taxes.
Telephone Orders – If ordering by telephone, a $10 processing fee* and actual freight costs will be added to the order.
Sales Tax – All U.S. purchases must include applicable state and local sales tax. Customers claiming tax-exempt status must provide Global with a copy of their exemption certificate.
Shipping (U.S. Orders) – Orders shipped within the U.S. are sent via traceable means. Most orders are shipped the same day. Subscription updates are sent by First-Class Mail. Other options, including next-day service, air service, and fax transmission are available at additional cost. Call 1-800-854-7179 for more information.
Shipping (International Orders) – Standard international shipping is by air express courier service. Subscription updates are sent by World Mail. Normal delivery is 3-4 days from shipping date.
Rush Shipping Fee – Next Day Delivery orders charge is $20 in addition to the carrier charges. Next Day Delivery orders must be placed by 2:00 p.m. MST to ensure overnight delivery.
Returns – All returns must be pre-approved by calling Global's Customer Service Department at 1-800-624-3974 for information and assistance. There may be a 15% restocking fee. Special order items, electronic documents, and age-dated materials are non-returnable.
***Minimum Order –** There is a $50 minimum for all orders containing hardcopy documents. The $50 minimum applies to the order subtotal including the $10 processing fee, excluding any applicable taxes and freight charges. If the total cost of the documents on the order plus the $10 processing fee is less than $50, the processing fee will be increased to bring the order amount up to the $50 minimum. This processing fee will be applied before any applicable deposit account, quantity or member discounts have been applied. There is no minimum for orders containing only electronically delivered documents.

Additional copies are available through Global Engineering Documents at (800) 854-7179 or (303) 397-7956

Information about API Publications, Programs and Services is available on the World Wide Web at: http://www.api.org

American Petroleum Institute

1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Product No. C66007