INTERNATIONAL STANDARD

ISO 16812

Second edition
2007-02-15

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

Industries du pétrole, de la pétrochimie et du gaz naturel — Échangeurs de chaleur à faisceaux

Reference number
ISO 16812:2007(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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 2.

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 document 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, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

This second edition cancels and replaces the first edition (ISO 16812:2002), which has been technically revised.

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.

Annex A provides some optional recommended practices.

A bullet (●) at the beginning of a clause or subclause indicates a requirement for the purchaser to make a decision or provide information (see checklist in Annex B).

In this International Standard, where practical, US Customary (USC) units are included in parentheses for information.

Petroleum, petrochemical 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, petrochemical 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

ASME B 16.5[1], *Pipe Flanges and Flanged Fittings*

ASME B 16.11, *Forged Fittings, Socket-Welding and Threaded*

ASME B 1.20.1, *Pipe Threads, General Purpose (Inch)*

EJMA[2], *Standards of the Expansion Joint Manufacturers Association*

NACE MR0103[3], *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

TEMA Standards Set[4], 8th Edition, *Standards of the Tubular Exchanger Manufacturers Association*

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

2) Expansion Joint Manufacturers Association, 25 North Broadway, Tarrytown, NY 10591, USA.

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

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

3 Terms and definitions

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

3.1
annular distributor
additional chamber incorporated into a shell side nozzle to more evenly distribute shell side fluids entering or exiting the tube bundle

3.2
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

3.3
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

3.4
communicating chamber
heat-exchanger appurtenance that intersects the shell or heads of the heat exchanger and forms an integral part of the pressure-containing envelope

EXAMPLES Sump, annular distributor.

3.5
effective surface
outside surface area of the tubes that contributes to heat transfer

3.6
full-penetration weld
welded joint that results in weld metal through the entire thickness of the components being joined

3.7
heat-exchanger unit
one or more heat exchangers for a specified service that may include alternative operating conditions

3.8
hydrogen service
service that contains hydrogen at a partial pressure exceeding 700 kPa (100 psi) absolute

3.9
item number
purchaser's identification number for a heat-exchanger unit

3.10
nubbin
projection on the flange gasket surface, positioned at the centre of the gasket, used to concentrate the bolt load on the gasket

3.11
pressure design code
recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLES ASME Section VIII, EN 13445.

3.12
seal-welded
tube-to-tubesheet joint weld of unspecified strength applied between the tubes and tubesheets for the sole purpose of reducing the potential for leakage

3.13
strength-welded
tube-to-tubesheet joint welded so that the design strength is equal to, or greater than, the axial tube strength specified by the pressure design code

4 General

4.1 The pressure design code shall be specified or agreed 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 (8th edition), 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 Annex A includes some recommended mechanical and design details for information.

4.5 Annex B provides a checklist that can be used by the purchaser to ensure that bulletted items in this International Standard are addressed.

4.6 Annex C provides examples of data sheets.

4.7 Annex D includes a recommended division of responsibility for completing the data sheet.

5 Proposals

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

5.2 Designs that are not fully defined by the nomenclature in TEMA (8th edition), Section 1, shall be accompanied by sketches that are sufficient to describe the details of construction.

5.3 If an annular distributor is provided, the vendor shall define the type of construction proposed.

5.4 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.

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

5.6 For stacked heat exchangers, the vendor shall supply the following components unless otherwise specified by the purchaser:

a) bolts, nuts and gaskets for interconnecting nozzles;

b) shims and bolting for interconnecting supports.

5.7 The vendor shall provide a separate quotation for the following items unless otherwise specified by the purchaser:

a) a test component consisting of a test ring and gland, in accordance with TEMA (8th edition), 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 and other supporting data

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

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

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

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

e) coupling sizes, rating and orientation;

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

g) overall dimensions of the heat exchanger;

h) tube-bundle removal clearance;

i) mass of the heat exchanger, empty and full of water, and of removable components with a mass greater than 25 kg (60 lb) (e.g. removable tube bundle, channel, channel cover and shell cover);

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

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

l) requirements for post-weld heat treatment;

m) requirements for radiographic examination;

n) requirements for material impact testing;

o) requirements for surface preparation and painting;

p) gasket materials;

q) insulation thickness;

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

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

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

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

6.1.2 The vendor shall submit flow-induced vibration analysis, if specified by the purchaser.

6.2 Information required after outline 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. These 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;

k) special installation and maintenance instructions including lifting and handling.

6.2.4 The vendor shall submit for the purchaser's review the following documentation.

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. The formulas in the applicable sections of the pressure design code and TEMA shall be referenced.

b) Design calculations based on seismic, wind, 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 or hydraulic tensioning devices) are used. Any required lubricants shall be stated.

d) Design calculations for thermal loads imposed on nozzles of stacked heat exchangers.

- **6.2.5** The vendor shall submit design calculations for supports or lifting and pulling devices, 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 following documents in the format and quantities specified by the purchaser:

a) “as-built” data 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 post-weld heat treatments;

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

h) nameplate rubbing or a facsimile;

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

j) non-destructive examination (NDE) map;

k) all associated NDE reports, including radiographic, magnetic-particle, liquid-penetrant, ultrasonic, hardness, impact, positive material identification (PMI) and any other reports as applicable;

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

m) 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 C).

7.1.2 The design temperature of a component (including external bolting) influenced by both the shell side and tube side fluids 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 C).

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 or approved by the purchaser.

7.2.2 The minimum cladding thickness at the tube side face of a tubesheet shall not be less than 10 mm (3/8 in) when tubes are expanded only, and 5 mm (3/16 in) when tubes are welded to the tubesheet. The minimum cladding thickness on the shell side face shall not be less than 10 mm (3/8 in). Weld overlays shall have sufficient thickness to provide the specified chemical composition to a depth of at least 1,5 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 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) The 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) The 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 loads without suffering distortion that can 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).