INTERNATIONAL STANDARD

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

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

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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

This International Standard is based on API Standard 660, sixth edition, February 2001.

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 enquiry 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 steel 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

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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 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 enquiry 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 enquiry, 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 enquiry.

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 post-weld 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 overlays 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.