INTERNATIONAL STANDARD

ISO 13706

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Petroleum and natural gas industries — Air-cooled heat exchangers

Industries du pétrole et du gaz naturel — Échangeurs de chaleur refroidis à l'air

Reference number
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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.

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.

International Standard ISO 13706 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 and C of this International Standard are for information only.

Introduction

This International Standard is based on API standard 661, fourth edition, November 1997.

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.

Petroleum and natural gas industries — Air-cooled heat exchangers

1 Scope

This International Standard gives requirements and recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of air-cooled heat exchangers for use in the petroleum and natural gas industries.

This International Standard is applicable to air-cooled heat exchangers with horizontal bundles, but the basic concepts may also be applied to other configurations.

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.

ISO 76, *Rolling bearings — Static load ratings.*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life.*

ISO 286 (all parts), *ISO system of limits and fits.*

ISO 1081, *Belt drive — V-belts and V-ribbed belts, and corresponding grooved pulleys — Vocabulary.*

ISO 1459, *Metallic coatings — Protection against corrosion by hot-dip galvanizing — Guiding principles.*

ISO 1461, *Hot-dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods.*

ISO 2491, *Thin parallel keys and their corresponding keyways (dimensions in millimetres).*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 4183, *Belt drives — Classical and narrow V-belts — Grooved pulleys (system based on datum width).*

ISO 4184, *Belt drives — Classical and narrow V-belts — Lengths in datum system.*

ISO 5287, *Narrow V-belt drives for the automotive industry — Fatigue test.*

ISO 5290, *Belt drives — Grooved pulleys for joined narrow V-belts — Groove sections 9J, 15J, 20J and 25J (effective system).*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

ISO 9563, *Belt drives — Electrical conductivity of antistatic endless synchronous belts — Characteristics and test method.*

ISO 10436, *Petroleum and natural gas industries — General-purpose steam turbines for refinery service.*

AGMA 6001[1)], *Design and selection of components for enclosed gear drives.*

AGMA 6010-E, *Practice for enclosed speed reducers or increasers using spur, helical, herringbone and spiral bevel gears*.

ICBO[2)], *Uniform Building Code.*

3 Terms and definitions

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

3.1
bank
one or more items arranged in a continuous structure

3.2
bare tube surface
total area of the outside surfaces of the tubes, based on the length measured between the outside faces of the header tubesheets

3.3
bay
one or more tube bundles, serviced by two or more fans, including the structure, plenum and other attendant equipment

NOTE Figure 1 shows typical bay arrangements.

3.4
finned surface
<of a tube> total area of the outside surface exposed to air

3.5
forced-draught exchanger
exchanger designed with the tube bundles located on the discharge side of the fan

3.6
induced-draught exchanger
exchanger designed with the tube bundles located on the suction side of the fan

3.7
item
one or more tube bundles for an individual service

1) American Gear Manufacturers' Association, 1500 King Street, Suite 201, Alexandria, VA 22314, USA.

2) International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601, USA.

3.8
item number
purchaser's identification number for an item

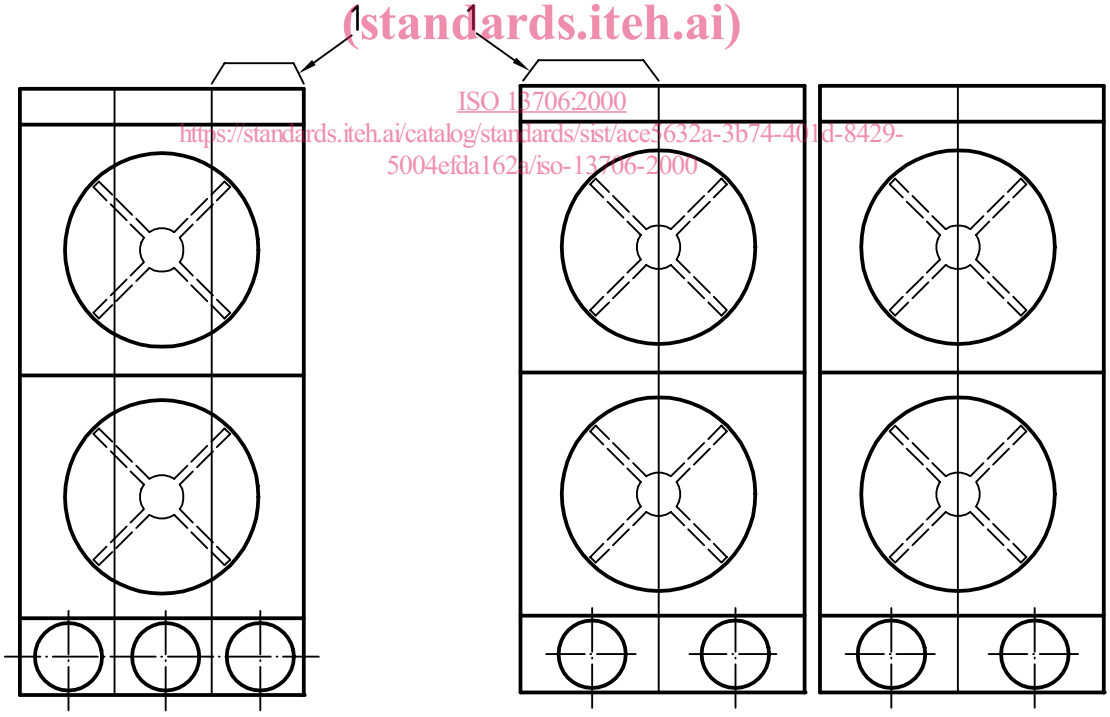
3.9
pressure design code
recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME VIII.

3.10
structural code
recognized structural standard specified or agreed by the purchaser

EXAMPLES AISC M011 and AISC S302.

3.11
tube bundle
assembly of headers, tubes and frames



a) One-bay **b) Two-bay**

Key
1 Tube bundle

Figure 1 — Typical bay arrangements

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.

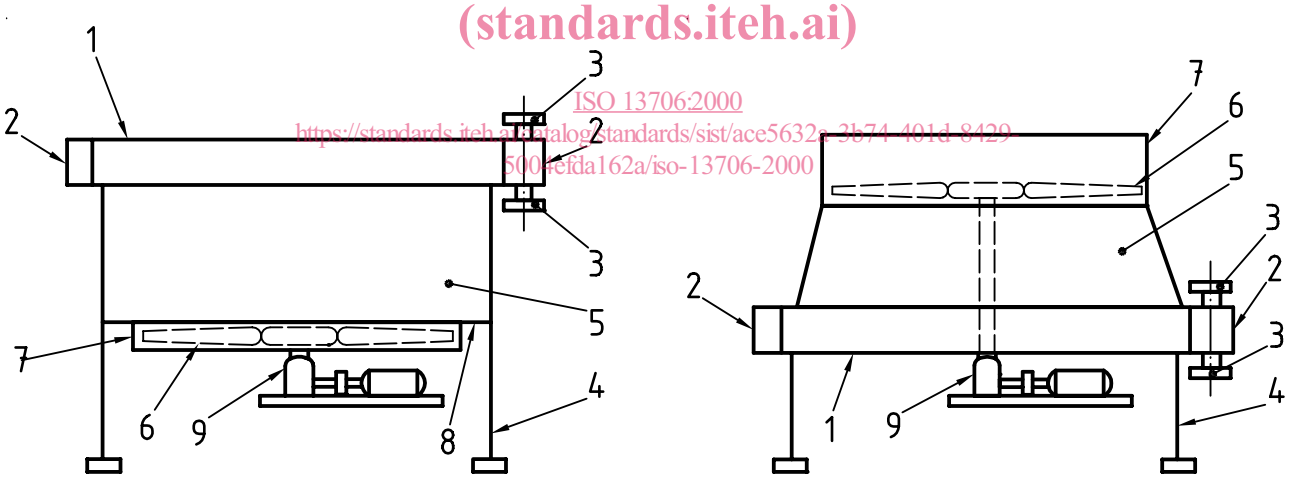
NOTE A round bullet (●) at the beginning of a subclause indicates a requirement for the purchaser to make a decision or provide information (see checklist in annex B). A triangular bullet (▲) at the beginning of a subclause indicates that this detail is included on the air-cooled heat exchanger data sheet (see annex B).

4.2 The air-cooled heat exchanger shall be either a forced-draught exchanger or an induced-draught exchanger and shall include the components shown in Figure 2 and any auxiliaries such as ladders, walkways and platforms.

4.3 Annex A, which may be consulted if required, includes for information some recommended mechanical and design details. Annex A also includes precautions for consideration when specifying certain design aspects, including temperature limitations, type of extended surface, tube support methods, type of air-cooled heat exchanger, materials of gasket construction and operational considerations such as walkway access.

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

4.5 In this International Standard, where practical, U.S. Customary units are included in brackets for information.



a) Forced draught **b) Induced draught**

Key

1 Tube bundle
2 Header
3 Nozzle
4 Supporting column
5 Plenum
6 Fan
7 Fan ring
8 Fan deck
9 Drive assembly

Figure 2 — Typical components of an air-cooled heat exchanger

5 Proposals

5.1 The vendor's proposal shall include a completed data sheet for each item (see annex B).

5.2 A proposal drawing shall be furnished which shows the major dimensions in plan and elevation, and the nozzle sizes and their orientation.

5.3 The proposal shall state whether vertically mounted electric motors shall be shaft up or shaft down.

5.4 The fabrication procedure and welding procedure shall be furnished for welded tube-to-tubesheet joints.

5.5 The proposal shall fully define the extent of shop assembly and include a general description of the components to be assembled in the field.

5.6 Any proposal for a design that is not fully described in this International Standard shall include additional drawings sufficient to describe the details of construction.

5.7 The proposal shall include a detailed description of any exceptions to the specified requirements.

- **5.8** The proposal shall include noise data. The proposal shall include a noise data sheet (see annex B) if specified by the purchaser.

- **5.9** The proposal shall include fan performance characteristic curves if specified by the purchaser.

5.10 The proposal shall include details of the method used to secure the fin ends (7.1.11.7).

5.11 The vendor shall inform the purchaser if the vendor considers that the requirements specified by the purchaser are in conflict with, or are not suitable for, the intended purposes or operation of the unit.

6 Documentation

6.1 Approval information

- **6.1.1** For each item number, the vendor shall produce documents which include the following information. The purchaser shall specify which documents shall be submitted and which of them shall be subject to approval.

a) The purchaser's item number, the service, the project name and location, the purchaser's order number and the vendor's shop order number;

b) design pressure, maximum allowable working pressure, test pressure, maximum and minimum design temperature, and corrosion allowance;

c) any applicable codes and purchase specifications of the purchaser;

d) material specifications and grades for all pressure parts;

e) overall dimensions;

f) dimensions and locations of supports and sizes of holding-down bolts;

g) nozzle size, rating, facing, location, projection beyond header surface, allowable loadings (forces and moments) and direction of flow;

h) drive mount details;

i) masses of the tube bundle, the exchanger empty and full of water, and the mass of the heaviest component or combination of components intended by the vendor to be handled in a single lift;

j) column reactions for each load type listed in 7.3.3;

k) post-weld heat treatment requirements;

l) radiographic and other non-destructive examination requirements;

m) surface preparation and painting requirements;

n) design exposure temperatures for mechanical and instrumentation components;

o) nameplate and its position;

p) tube-to-tubesheet joint and details of joint preparation.

6.1.2 The vendor shall also furnish gasket detail drawings, field assembly drawings, and drawings for all auxiliary equipment and controls furnished. Drawings shall show electrical and control connections, including those of motive and signal air for any pneumatically actuated louvres or fans. The gasket details shall include type and material, and shall be shown on a separate drawing.

- **6.1.3** Calculations required by the pressure design code shall be made for the design of pressure components, including header boxes, tubes and tube joints. Additionally, sufficient detail shall be supplied for any non-standard pressure boundary components, such as swage-type transition nozzles. If specified by the purchaser, the calculations shall be submitted for approval.

- **6.1.4** If specified by the purchaser, weld maps, all proposed welding procedures and qualifications (including impact test results, if applicable) shall be submitted for approval prior to fabrication.

- **6.1.5** Further engineering information required from the vendor for installation, operation, maintenance, or inspection shall be a matter of agreement between the purchaser and the vendor.

6.2 Final records

6.2.1 The vendor shall maintain records of the materials used and fabrication details for at least 5 years.

- **6.2.2** The purchaser shall specify which of the following shall be furnished, and shall specify if any of them shall be in an electronic medium:

a) an “as-built” data sheet, including material specifications and grades for all pressure parts;

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

c) certified material test reports for all pressure parts;

d) fan and hub data, including shaft bore and keyway dimensions and coupling and sheave data;

e) a schematic diagram for automatically controlled fan pitch or louvre blade adjustment, if the controller is furnished by the vendor;

f) installation, operation and maintenance instructions, including the type of lubrication furnished for gears and bearings;

g) parts list;

h) a certified noise data sheet for the air-cooled heat exchanger with the fans operating at rated speed and at design conditions;

i) fan performance characteristic curves showing the operating point and shaft power consumption;

j) louvre characteristic performance curve;

k) temperature recorder charts made during postweld heat treatment of the headers.

7 Design

7.1 Tube bundle design

7.1.1 General

7.1.1.1 Tube bundles shall be rigid, self-contained, and designed for handling as a complete assembly.

7.1.1.2 The vendor shall make provision for lateral movement of exchanger tube bundles of at least 6 mm ($^1/_4$ inch) in both directions or at least 12 mm ($^1/_2$ inch) in only one direction, unless the purchaser and the vendor agree on a greater movement.

7.1.1.3 Provision shall be made to accommodate thermal expansion of tubes.

7.1.1.4 All tubes shall be supported to prevent sagging and meshing or deformation of fins. Tube supports shall be spaced not more than 1,8 m (6 ft) from centre to centre.

7.1.1.5 A hold-down member (tube keeper) shall be provided at each tube support. Hold-down members shall be attached to side frames by bolting.

7.1.1.6 Tubes of single-pass condensers shall be sloped downward at least 10 mm per metre ($^1/_8$ inch per foot) towards the outlet header.

7.1.1.7 Tubes of multipass condensers need not be sloped.

7.1.1.8 Air seals shall be provided throughout the tube bundle and the bay to minimize air leakage and bypassing. Any air gap that exceeds 10 mm ($^3/_8$ inch) in width shall be sealed.

7.1.1.9 The minimum thickness of metal used for air seal construction shall be 2,5 mm (12 gauge USS, 0,105 inch) within the bundle side frame and 2,0 mm (14 gauge USS, 0,075 inch) outside the bundle side frame.

7.1.1.10 Bolts for removable air seals shall be at least 10 mm ($^3/_8$ inch) nominal diameter.

- **7.1.1.11** Winterization shall be as specified or agreed by the purchaser. Annex C should be used.

- **7.1.1.12** The exchanger shall be designed for an internal steam-out operation at the temperature, pressure, and operating conditions specified by the purchaser.

7.1.2 Heating coils

7.1.2.1 Heating coils provided to protect the tube bundle against freeze-up shall be in a separate bundle, and not part of the tube bundle.

7.1.2.2 Heating coils shall cover the full width of the tube bundle.

7.1.2.3 The tube pitch of the heating coil shall not exceed twice the tube pitch of the tube bundle.

7.1.2.4 If steam is used as heating fluid, heating coils shall be single pass, and the tubes shall be sloped downward at least 10 mm per metre ($^1/_8$ inch per foot) towards the outlet.

7.1.2.5 Pipe-type headers with welded-in tubes may be used for steam service.

7.1.3 Tube bundle design temperature

- **7.1.3.1** The maximum and minimum design temperatures for pressure parts shall be as specified by the purchaser or, if not specified by the purchaser, the maximum design temperature shall be at least the specified process fluid inlet temperature plus 25 °C (50 °F).

● **7.1.3.2** The purchaser shall separately specify the maximum operating temperature to be applied for fin type selection (the fin design temperature). The design temperatures for pressure parts are not intended to govern fin type selection or to apply in determining exposure temperatures of mechanical and instrumentation components.

7.1.4 Tube bundle design pressure

● The design pressure shall be as specified by the purchaser or, if not specified, shall be the greater of the following:

a) the inlet pressure plus 10 %;

b) the inlet pressure plus 170 kPa (25 psi).

7.1.5 Corrosion allowance

▲ **7.1.5.1** The corrosion allowance shall be as specified by the purchaser for all surfaces exposed to the process fluid, except that no corrosion allowance shall be provided for tubes, gaskets or gasket contact surfaces. If not specified, a minimum corrosion allowance of 3 mm ($^1/_8$ inch) shall be provided for carbon and low-alloy steel components.

7.1.5.2 The corrosion allowance shall be provided on each side of pass partition plates or stiffeners.

7.1.5.3 A thickness equal to the depth of the pass partition groove may be considered as available corrosion allowance on grooved cover plate and tubesheet surfaces.

7.1.6 Headers

7.1.6.1 General

● **7.1.6.1.1** Headers shall be designed to prevent excessive warpage of tubesheets and/or leakage at tube joints. The analysis shall consider maximum operating temperature and maximum cooling conditions at minimum ambient air temperature. If specified by the purchaser, the analysis shall consider alternative operations such as low process flow at low ambient air temperature, freezing of fluids in tubes, steam-out, loss of fans due to power failure, and cycling conditions.

7.1.6.1.2 If the fluid temperature difference between the inlet and the outlet of a multi-pass bundle exceeds 110 °C (200 °F), U-tube construction, split headers or other methods of restraint relief shall be employed.

7.1.6.1.3 The need for restraint relief in single- or multi-pass bundles shall be investigated regardless of the fluid temperature difference between the inlet and outlet of the bundle. The designer shall provide calculations to prove the adequacy of the design. Calculations shall consider the following stress combinations:

a) For tube stress and/or tube joint stress:

   1) stress caused by pressure and temperature;

   2) stress caused by nozzle forces and moments;

   3) stress caused by differential tube expansion (including that caused by waxing or fouling) between rows/passes in the coil sections;

   4) stress caused by lateral header movement.

   Some of the above stresses are additive, and tube joint efficiency shall be considered.

b) For header and nozzle stress:

   1) stress caused by temperature and pressure;

2) stress caused by nozzle forces and moments;

3) stress caused by lateral header movement;

4) stress caused by differential tube expansion between rows/passes in the coil sections.

NOTE Set-in versus set-on nozzle attachments could greatly affect the above.

c) For header attachments and supports (including coil side frames and cooler structure):

1) stress caused by header mass and water;

2) stress caused by nozzle forces and moments;

3) stress caused by lateral header movement;

4) stress caused by tube expansion.

NOTE There may be additional loads and stresses imposed on the tube bundle which may not have been stated above (e.g. seismic).

7.1.6.1.4 Headers shall be designed so that the cross-sectional flow area of each pass is at least 100 % of the flow area in the corresponding tube pass.

7.1.6.1.5 The lateral velocity in the header shall not exceed the velocity in the nozzle. Multiple nozzles or an increased header cross-sectional area may be required.

7.1.6.1.6 The minimum nominal thickness of header components shall be as shown in Table 1.

Table 1 — Minimum nominal thickness of header components

Component	Minimum thickness	
	Carbon or low-alloy steel	High-alloy steel or other material
Tubesheet	20 mm ($^3/_4$ inch)	15 mm ($^5/_8$ inch)
Plug sheet	20 mm ($^3/_4$ inch)	15 mm ($^5/_8$ inch)
Top, bottom and end plates	12 mm ($^1/_2$ inch)	10 mm ($^3/_8$ inch)
Removable cover plates	25 mm (1 inch)	22 mm ($^7/_8$ inch)
Pass partition plates and stay plates	12 mm ($^1/_2$ inch)	6 mm ($^1/_4$ inch)

NOTE The thickness indicated for any carbon or low-alloy steel component includes a corrosion allowance of up to 3 mm ($^1/_8$ inch). The thickness indicated for any component of high-alloy steel or other material does not include a corrosion allowance. The thickness is based on an expanded tube-to-tubesheet joint with one groove.

7.1.6.1.7 Pass partitions used as stay plates for the tubesheet and plug sheet shall be made of one integral plate.

7.1.6.1.8 Header types other than those described in 7.1.6.2 or 7.1.6.3 may be proposed as an alternative design (see clause 12).