

BS EN ISO 13706:2011



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Petroleum, petrochemical and natural gas industries — Air-cooled heat exchangers (ISO 13706:2011)

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The UK participation in its preparation was entrusted to Technical Committee PSE/17/-/6, Processing equipment and systems for petroleum and natural gas industries.

A list of organizations represented on this committee can be obtained on request to its secretary.

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heat exchangers (ISO 13706:2011)

Industries du pétrole, de la pétrochimie et du gaz naturel -
Échangeurs de chaleur refroidis à l'air (ISO 13706:2011)

Erdöl- petrochemische und Erdgasindustrie - Luftgekühlte
Wärmeaustauscher (ISO 13706:2011)

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Foreword

This document (EN ISO 13706:2011) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2012, and conflicting national standards shall be withdrawn at the latest by June 2012.

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Endorsement notice

The text of ISO 13706:2011 has been approved by CEN as a EN ISO 13706:2011 without any modification.

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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.

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ISO 13706 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 third edition cancels and replaces the second edition (ISO 13706:2005), which has been technically revised.

Introduction

It is necessary that users of this International Standard be aware that further or differing requirements can 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 can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this International Standard and provide details.

Petroleum, petrochemical 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, petrochemical and natural gas industries.

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

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 76, *Rolling bearings — Static load ratings*

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

ISO 286 (all parts), *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes*

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

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 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, *Belt drives — Narrow V-belts for the automotive industry — Fatigue test*

ISO 5290, *Belt drives — Grooved pulleys for joined narrow V-belts — Groove sections 9N/J, 15N/J and 25N/J (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 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production*

AGMA 6001¹⁾, *Design and Selection of Components for Enclosed Gear Drives*

ANSI/AGMA 6010, *Spur, Helical, Herringbone and Bevel Enclosed Drives*

ASME PTC 30²⁾, *Air-Cooled Heat Exchangers*

ICC³⁾, *International Building Code*

NACE MR0103⁴⁾, *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE SP0472, *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*

3 Terms and definitions

For the purposes of this document, 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

critical process temperature

temperature related to important physical properties of a process stream

EXAMPLES Freezing point, pour point, cloud point, hydrate formation temperature and dew point.

3.5

cyclic service

process operation with periodic variation in temperature, pressure, and/or flowrate

3.6

exhaust air

air that is discharged from the air-cooled heat exchanger to the atmosphere

3.7

external recirculation

process that uses an external duct to carry recirculated air to mix with and heat the inlet air

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

2) American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA.

3) International Code Council Foundation, 10624 Indian Woods Drive, Cincinnati, OH 45242, USA.

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

3.8

finned surface

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

3.9

forced-draught exchanger

exchanger designed with the tube bundles located on the discharge side of the fan

3.10

geometric centre

location at the centre of a bay on a plane midway between the air inlet and the air outlet for both forced-draft and induced-draft units

NOTE The geometric centre is also considered the acoustic centre of a bay for calculations.

3.11

hydrogen service

services that contain hydrogen at a partial pressure exceeding 700 kPa (100 psi) absolute

3.12

induced-draught exchanger

exchanger designed with the tube bundles located on the suction side of the fan

3.13

inlet air

atmospheric or ambient air that enters the air-cooled heat exchanger

3.14

internal recirculation

process that uses fans (possibly with louvres) to recirculate air from one part of the process bundle to the other part

3.15

item

one or more tube bundles for an individual service

3.16

item number

purchaser's identification number for an item

3.17

measurement surface

surface of the bay or the cylinder or sphere on which sound-pressure level is measured

3.18

minimum design air temperature

specified inlet air temperature that is used for winterization

3.19

minimum design metal temperature

lowest metal temperature at which pressure-containing elements can be subjected to design pressure

3.20

octave bands

preferred frequency bands

3.21

pressure design code

recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME BPVC VIII.

3.22

recirculated air

air that has passed through the process bundle and is redirected to mix with and heat the inlet air

3.23

specified minimum tube-wall temperature

critical process temperature plus a safety margin

3.24

structural code

recognized structural standard specified or agreed by the purchaser

EXAMPLES AISC M011 and AISC S302.

3.25

tube bundle

assembly of headers, tubes and frames

3.26

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

3.27

sound level

sound-pressure level when frequency is weighted according to the standardized A, B, or C weighting used in sound-level meters

NOTE Only A-weighted readings [dB(A)] are referenced in this International Standard.

3.28

sound-power level

ten times the logarithm to base 10 of the ratio of the total acoustic power radiated by a sound source to the reference power of 10^{-12} W

3.29

sound-pressure level

twenty times the logarithm to base 10 of the ratio of the root mean square sound pressure to the reference sound pressure of 2×10^{-5} N/m²

3.30

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

3.31

unit

one or more tube bundles in one or more bays for an individual service

3.32

wind skirt

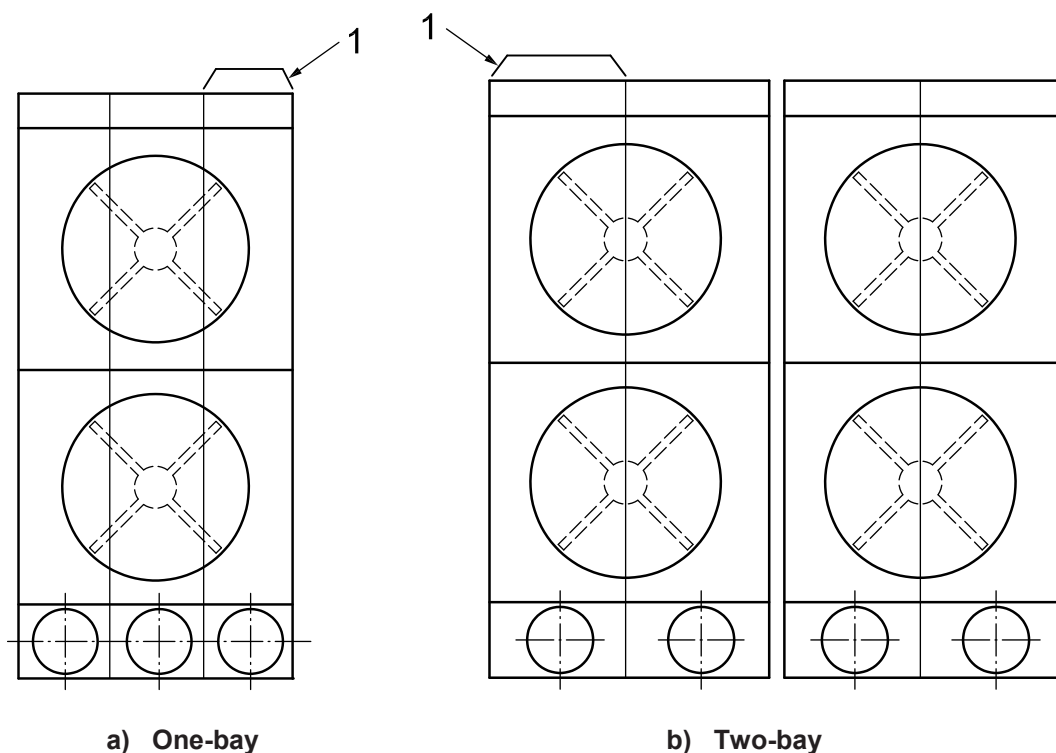
vertical barrier either above or below an air-cooled heat exchanger that minimizes the effect of wind

3.33

winterization

provision of design features, procedures, or systems for air-cooled heat exchangers to avoid problems with the process fluid as a result of low-temperature inlet air

NOTE Problems related to low-temperature inlet air include fluid freezing, cooling to the pour point, wax formation, hydrate formation, laminar flow, and condensation at the dew point (which can initiate corrosion).



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 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).

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 (see A.2).

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, US Customary (USC) and other commonly used units are included in brackets for information.

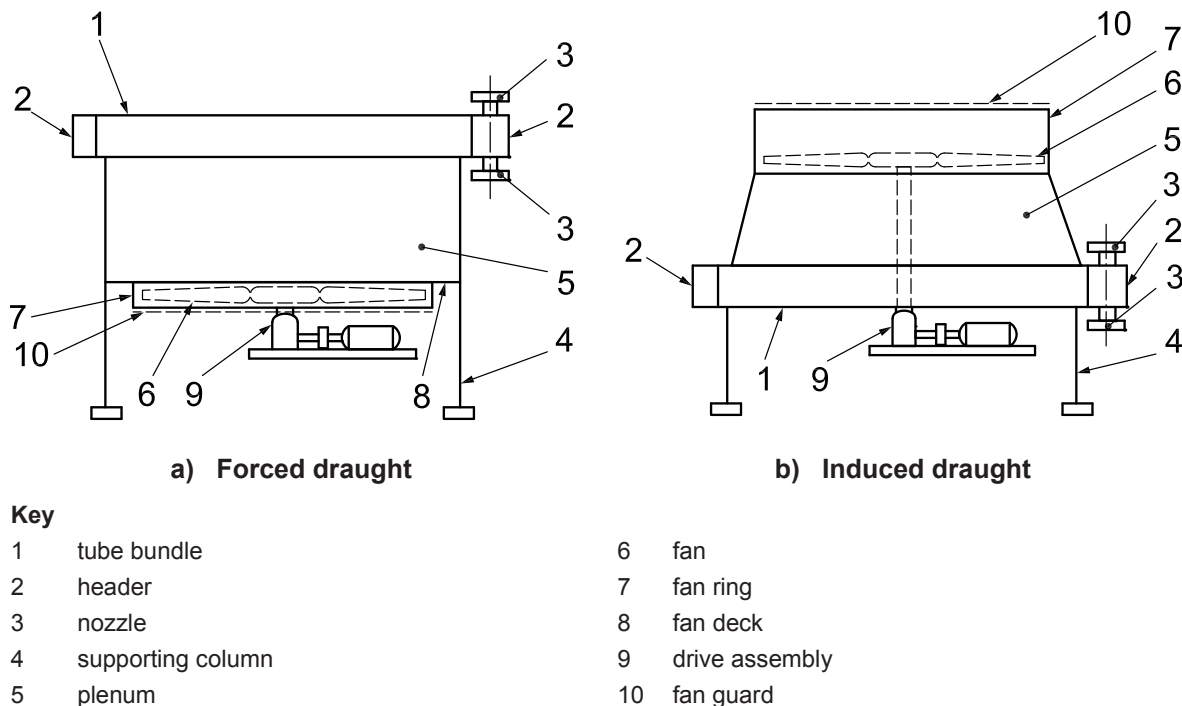


Figure 2 — Typical components of an air-cooled heat exchanger

- **4.6** The purchaser shall specify if the service is designated as sour in accordance with ISO 15156 (all parts) for oil and gas production facilities and natural gas sweetening plants, or designated as wet hydrogen sulfide service in accordance with NACE MR0103 for other applications (e.g. petroleum refineries, LNG plants and chemical plants), in which case all materials in contact with the process fluid shall meet the requirements of the applicable NACE standard to mitigate the potential for sulfide stress cracking (SSC). Identification of the complete set of materials, qualification, fabrication, and testing specifications to prevent in-service environmental cracking is the responsibility of the user (purchaser).

NOTE For the purpose of this provision NACE MR0175 is equivalent to ISO 15156 (all parts).

- **4.7** The requirement for winterization and its type shall be specified by the purchaser. Annex C contains guidance on various methods of winterization for air-cooled heat exchangers.

5 Proposals

- 5.1** The vendor's proposal shall include a completed data sheet for each item (see example in Annex B).
- 5.2** A proposal drawing that shows the major dimensions in plan and elevation, and the nozzle sizes and their orientation shall be furnished.
- 5.3** The proposal shall state whether vertically mounted electric motors shall be shaft up or shaft down.
- 5.4** The proposal shall fully define the extent of shop assembly and include a general description of the components for assembly in the field.

5.5 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.

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

- **5.7** The proposal shall include noise data. The proposal shall include a noise data sheet (see example in Annex B) if specified by the purchaser.

5.8 The proposal shall include fan performance characteristic curves with the design point marked on the curves.

5.9 The proposal shall include details of the method used to secure the fin ends; see 7.1.11.7.

5.10 The proposal for an air-cooled exchanger with a recirculation system (as described in Annex C) shall include drawings showing the duct and plenum sizes, net free flow area, louvre type and arrangement, drive location, and proposed control schematic.

6 Documentation

6.1 Approval information

- **6.1.1** For each item number, the vendor shall produce documents that include the following information. The purchaser shall specify which documents shall be submitted and which of them shall be subject to approval.
 - a) purchaser's item number, service, project name and location, purchaser's order number and vendor's shop order number;
 - b) design pressure, maximum allowable working pressure, test pressure, maximum and minimum design temperature, and corrosion allowance;
 - c) fan performance characteristic curves with the design point marked on the curve, including fan critical speeds for use with variable-frequency drives;
 - d) any applicable codes and purchase specifications of the purchaser;
 - e) material specifications and grades for all pressure parts;
 - f) overall dimensions;
 - g) dimensions and locations of supports and sizes of holding-down bolts;
 - h) nozzle size, rating, facing, location, projection beyond header surface, allowable loadings (forces and moments) and direction of flow;
 - i) drive mount details;
 - j) 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 for handling in a single lift;
 - k) column reactions for each load type listed in 7.3.3;
 - l) post-weld heat treatment requirements;
 - m) U-bend heat treatment or annealing procedure;
 - n) radiographic and other non-destructive examination requirements;
 - o) surface preparation and painting requirements;

- p) design exposure temperatures for mechanical and instrumentation components;
- q) nameplate and its position;
- r) tube-to-tubesheet joint and details of joint preparation;
- s) maximum and minimum plug torque values with recommended thread lubrication;
- t) when sour or wet sulfide service is specified by the purchaser, a certified material test report (CMTR) shall be supplied for all carbon steel materials in contact with the process fluid.

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 louvers or fans. The gasket details shall include type and material, and shall be shown on a separate drawing.

- **6.1.3** If specified by the purchaser, calculations required by the pressure design code shall be provided for the design of pressure components, including header boxes, tubes and tube joints. Sufficient detail shall be supplied for any non-standard pressure boundary components, such as swage type transition nozzles. Calculations shall also be provided for restraint relief in accordance with 7.1.6.1.3, and also for the defined external moments and forces on nozzles in accordance with 7.1.10.
- **6.1.4** If specified by the purchaser, weld maps, all proposed welding procedures, including tube to tubesheet welding procedures and qualifications (including impact test results, if applicable) shall be submitted for approval prior to fabrication.

6.1.5 If a hot air recirculation system is utilized for winterization, documents showing duct and plenum sizes, net free flow areas, louver types and arrangement, louver drive location(s), heating coil and heating medium consumption, and control scheme schematic shall be provided.

- **6.1.6** 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 10 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) "as-built" data sheet, including material specifications and grades for all pressure parts;
 - b) as-built shop drawings including details of headers and tube bundles; as-built shop drawings shall also be provided for any heating coils;
 - c) calculations as required by the pressure design code, including nozzle load confirmation, restraint relief and any finite element analysis;
 - d) certified motor drawing and completed motor data sheet for each size and type of motor;
 - e) manufacturer's data report in accordance with the pressure design code;
 - f) certified material test reports for all pressure parts;
 - g) fan and hub data, including shaft bore and keyway dimensions and coupling and sheave data;
 - h) schematic diagram for automatically controlled fan pitch or louver blade adjustment, if the controller is furnished by the vendor;

- i) installation, operation and maintenance instructions, including the type of lubrication furnished for gears and bearings;
- j) parts list;
- k) certified noise data sheet for the air-cooled heat exchanger with the fans operating at rated speed and at design conditions;
- l) fan performance characteristic curves showing the operating point and shaft power consumption;
- m) louvre characteristic performance curve;
- n) temperature recorder charts made during postweld heat treatment of the headers;
- o) non-destructive testing records;
- p) nameplate rubbing or facsimile.

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 ($\frac{1}{4}$ in) in both directions or 12,7 mm ($\frac{1}{2}$ in) in only one direction, unless the purchaser and the vendor agree on a different value.

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 1,83 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/m ($\frac{1}{8}$ in/ft) towards the outlet header.

7.1.1.7 The last pass of tubes in multi-pass condensers shall be sloped downward at least 10 mm/m ($\frac{1}{8}$ in/ft) towards the outlet header (see A.3.1).

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 ($\frac{3}{8}$ in) in width shall be sealed.

7.1.1.9 The minimum thickness of metal used for air seal construction shall be 2,7 mm (12 gauge USS); 0,105 in) within the bundle side frame and 1,9 mm (14 gauge USS; 0,08 in) outside the bundle side frame.

NOTE USS is US Standard for sheet and plate iron and steel.

7.1.1.10 Bolts for removable air seals shall be at least 10 mm ($\frac{3}{8}$ in) nominal diameter.

- **7.1.1.11** The exchanger shall be designed for an internal steam-out operation at the temperature, pressure, and operating conditions if specified by the purchaser.
- **7.1.1.12** The purchaser shall specify if cyclic service design is required. If cyclic service is specified, the purchaser shall specify the type and magnitude of variation in pressure, temperature and flowrate, the time for

the variation (hours, weeks, etc.) and the number of cycles or frequency for this variation expected during the life of the equipment. The extent and acceptance criteria of any required analysis shall be subject to the agreement of the purchaser (see A.2).

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 the smaller of twice the tube pitch of the tube bundle or 4,75 times the nominal heating coil tube diameter.

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/m ($1/8$ in/ft) towards the outlet.

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

7.1.3 Design temperature

- **7.1.3.1** The maximum and minimum design temperatures for pressure parts shall be as specified by the purchaser.
- **7.1.3.2** The purchaser shall separately specify the maximum operating temperature to apply 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 Design pressure

- The design pressure shall be as specified by the purchaser.

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 ($1/8$ in) 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 cyclic 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 requirement for restraint relief in single- or multi-pass exchangers shall be investigated regardless of the fluid temperature difference between the inlet and outlet of the exchanger. The vendor shall provide calculations to prove the adequacy of the design. Some of the stresses are additive, and tube-to-tubesheet joint efficiency shall be considered. Calculations shall consider the following stress combinations:

a) for tube stress and/or tube-to-tubesheet joint stress:

- 1) stress caused by differential tube expansion between rows/passes in the coil sections in both clean and fouled conditions,
- 2) stress caused by pressure,
- 3) stress caused by nozzle forces and moments,
- 4) stress caused by lateral header movement;

b) for header and nozzle stress:

- 1) stress caused by temperature and pressure,
- 2) stress caused by nozzle forces and moments,

NOTE Forces and moments can induce movement of the header; see note in 7.1.10.2.

- 3) stress caused by differential tube expansion between rows/passes in the coil sections;

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

- 1) stress caused by mass of the header full of water,
- 2) stress caused by nozzle forces and moments,

NOTE Forces and moments can induce movement of the header; see note in 7.1.10.2.

- 3) stress caused by tube expansion.

NOTE There can be additional loads and stresses imposed on the tube bundle that have not been mentioned above (e.g. seismic).

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

7.1.6.1.5 The lateral velocity in the header inlet compartment shall not exceed the velocity in the inlet nozzle. Multiple nozzles or an increased header cross-sectional area can 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 mm (in)	High-alloy steel or other material mm (in)
Tubesheet	19 ($\frac{3}{4}$)	16 ($\frac{5}{8}$)
Plug sheet	19 ($\frac{3}{4}$)	16 ($\frac{5}{8}$)
Top, bottom and end plates	12 ($\frac{1}{2}$)	10 ($\frac{3}{8}$)
Removable cover plates	25 (1)	22 ($\frac{7}{8}$)
Pass partition plates and stay plates	12 ($\frac{1}{2}$)	6 ($\frac{1}{4}$)
NOTE The thickness indicated for any carbon or low-alloy steel component includes a corrosion allowance of up to 3 mm ($\frac{1}{8}$ in). 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).

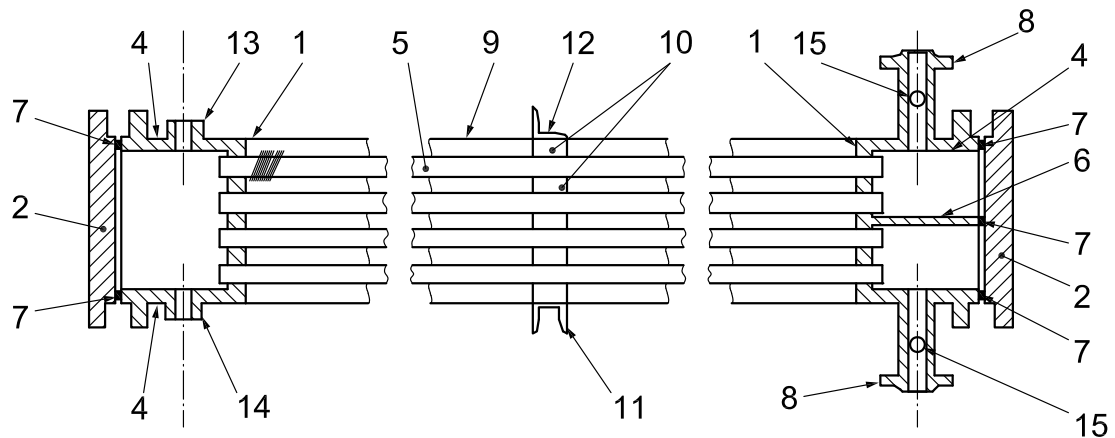
7.1.6.2 Removable cover plate and removable bonnet headers

7.1.6.2.1 The cover plate header design shall permit removal of the cover without disturbing header piping connections. Figure 3 a) shows the typical construction of tube bundles with removable cover plate headers.

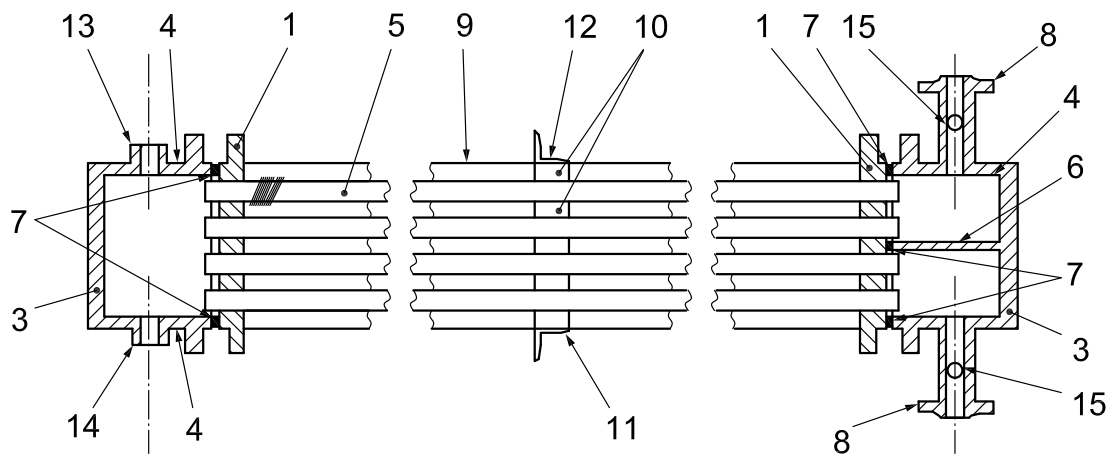
7.1.6.2.2 The bonnet header design shall permit removal of the bonnet with the minimum dismantling of header piping connections. Figure 3 b) shows typical construction of tube bundles with removable bonnet headers.

7.1.6.2.3 Bolted joints shall be designed using through bolts with either confined gaskets or unconfined full-face gaskets. Stud bolt construction may be used if approved by the purchaser. Gasket contact surfaces on cover plates, matching header box flanges and tubesheets shall be machined. The surface finish shall be appropriate for the type of gasket (See A.3.12). Typical constructions are shown in Figure 4. For hydrogen, sour, or wet hydrogen sulfide service, only confined gasket construction shall be used [see Figure 4 a) or 4 b)].

7.1.6.2.4 Either jackscrews or a minimum clearance of 5 mm ($\frac{3}{16}$ in) shall be provided at the cover periphery to facilitate dismantling.



a) Removable cover-plate header



b) Removable bonnet header

Key

1	tubesheet	6	pass partition	11	tube support cross-member
2	removable cover plate	7	gasket	12	tube keeper
3	removable bonnet	8	nozzle	13	vent
4	top and bottom plates	9	side frame	14	drain
5	tube	10	tube spacer	15	instrument connection

Figure 3 — Typical construction of tube bundles with removable cover plate and removable bonnet headers

7.1.6.2.5 Stay-bolts shall not be used.

7.1.6.2.6 For stud type construction, provision (e.g. sliding pins) shall be made to prevent damage to the studs during handling of the cover plate.

7.1.6.2.7 The minimum nominal diameter of through-bolts shall be 16 mm ($\frac{5}{8}$ in). The minimum nominal diameter of stud bolts shall be 20 mm ($\frac{3}{4}$ in).

7.1.6.2.8 The maximum spacing between bolt centres shall be in accordance with the pressure design code.

7.1.6.2.9 The minimum spacing between bolt centres shall be as shown in Table 2.

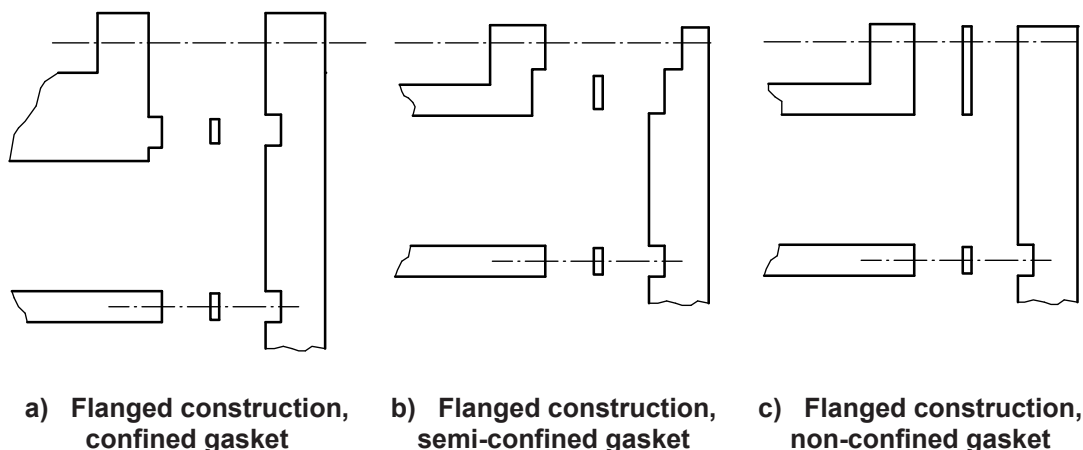


Figure 4 — Typical confined and full-faced gasket joint details

Table 2 — Minimum flange bolt spacing

Nominal bolt diameter mm (in)	Minimum bolt spacing mm (in)
16 ($\frac{5}{8}$)	38 ($1\frac{1}{2}$)
19 ($\frac{3}{4}$)	44 ($1\frac{3}{4}$)
22 ($\frac{7}{8}$)	52 ($2\frac{1}{16}$)
25 (1)	57 ($2\frac{1}{4}$)
29 ($1\frac{1}{8}$)	64 ($2\frac{1}{2}$)
32 ($1\frac{1}{4}$)	71 ($2\frac{13}{16}$)
35 ($1\frac{3}{8}$)	76 ($3\frac{1}{16}$)
38 ($1\frac{1}{2}$)	83 ($3\frac{1}{4}$)
41 ($1\frac{5}{8}$)	89 ($3\frac{1}{2}$)
44 ($1\frac{3}{4}$)	95 ($3\frac{3}{4}$)
48 ($1\frac{7}{8}$)	102 (4)
51 (2)	108 ($4\frac{1}{4}$)

7.1.6.2.10 Spacing between bolts straddling corners shall be such that the diagonal distance between bolts adjacent to the corner does not exceed the lesser of the spacing on the sides or the ends.

7.1.6.2.11 Allowable stresses that have been established on the basis of short-time tensile strength shall not be used for the design of flanges and gasketed flat covers.

NOTE 1 These allowable stresses can cause permanent deformation.

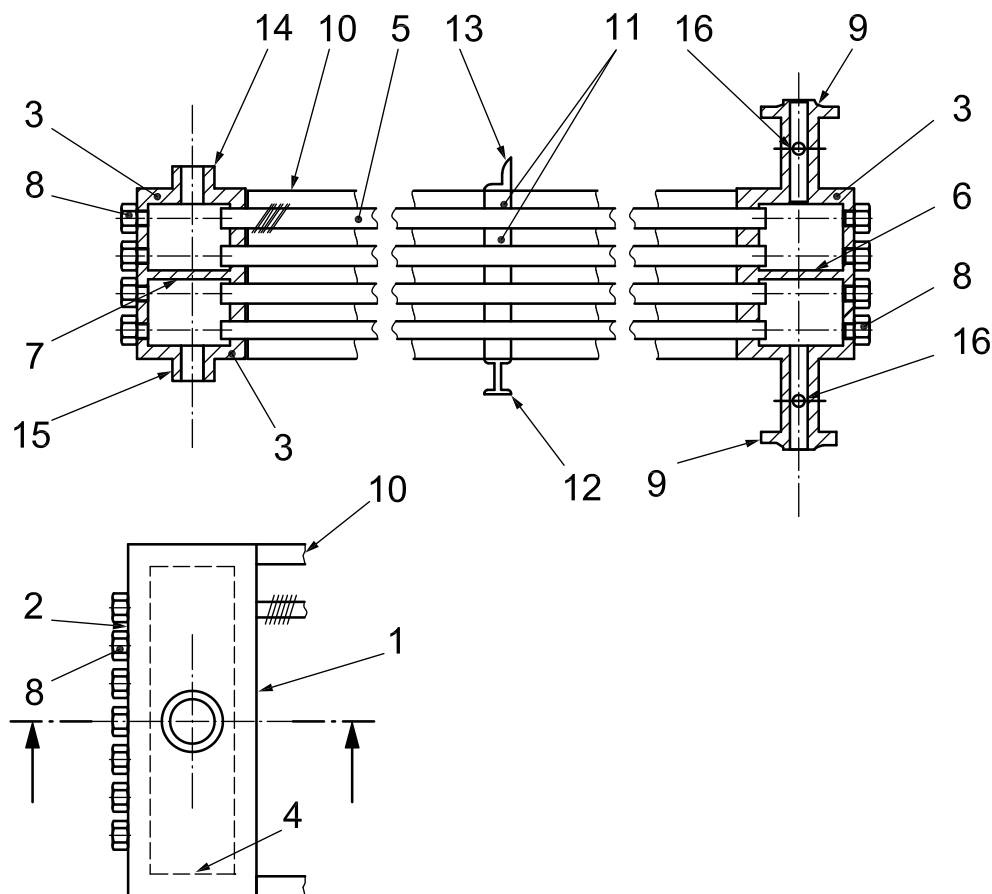
NOTE 2 In ASME BPVC II, the allowable stresses of some stainless steel alloys and high-nickel alloys have been established in this way.

7.1.6.3 Plug headers

7.1.6.3.1 Threaded plug holes shall be provided opposite the ends of each tube for access. Holes shall be threaded to the full depth of the plug sheet. Figure 5 shows typical construction of a tube bundle with plug headers.

7.1.6.3.2 The nominal thread diameter of the plug holes shall be equal to the outside diameter of the tube plus at least 3 mm ($\frac{1}{8}$ in).

7.1.6.3.3 Gasket contact surfaces of plug holes shall be spot-faced. The edges of the facing shall be free of burrs.



Key

1	tubesheet	7	stiffener	13	tube keeper
2	plug sheet	8	plug	14	vent
3	top and bottom plates	9	nozzle	15	drain
4	end plate	10	side frame	16	instrument connection
5	tube	11	tube spacer		
6	pass partition	12	tube support cross-member		

Figure 5 — Typical construction of a tube bundle with plug headers

7.1.7 Plugs for tube access

7.1.7.1 Plugs shall be the shoulder type with straight-threaded shanks.

7.1.7.2 Hollowed plugs shall not be used.

7.1.7.3 Plugs shall have hexagonal heads. The minimum dimension across the flats shall be at least equal to the plug shoulder diameter.

7.1.7.4 The pressure seal shall be maintained by means of a gasket between the flange of the plug and the plug sheet.

7.1.7.5 Positive means (such as a self-centring taper) shall be provided to ensure seating of the gasket in the spot-faced recess.

7.1.7.6 Plugs shall be long enough to fill the plug sheet threads, with a tolerance of $\pm 1,5$ mm ($^{1}_{16}$ in), except for galling materials or if the nominal plug sheet thickness is greater than 50 mm (2 in), for which alternative designs may be used with the approval of the purchaser. Additional factors to consider in selecting the plug design are thread interference, erosion, crevice corrosion and retention of fluid in cavities.

7.1.7.7 The thickness of the plug head from its gasket surface to the top face shall be at least 50 % of the nominal tube outside diameter. Greater thickness can be required due to pressure rating and material considerations.

7.1.7.8 Threads of plugs having nominal diameters 30 mm ($1\frac{1}{4}$ in) and smaller shall be fine series threads.

7.1.8 Gaskets

7.1.8.1 Plug gaskets shall be of the solid-metal type. The material of the plug gasket shall be the same type as that of the plug, unless otherwise agreed by the purchaser and vendor. Plug gasket hardness shall be less than that of the plug and the plug-sheet materials.

7.1.8.2 Plug gaskets shall be flat and free of burrs.

7.1.8.3 The minimum thickness of solid metal plug gaskets shall be 1,5 mm (0,060 in).

7.1.8.4 For the joint type shown in Figure 4 a), cover plate and bonnet gaskets shall be of the double-metal-jacketed, filled type or solid metal with a soft gasket seal facing. Filler material shall be non-asbestos and shall be suitable for sealing, exposure resistance and fire safety performance.

7.1.8.5 For the joint type shown in Figure 4 b), double-metal-jacketed, filled type gaskets or [at design pressures of 2 100 kPa gauge (300 psig) or less] compressed sheet composition gaskets suitable for the service shall be used. Gaskets shall be non-asbestos and shall be suitable for sealing, exposure resistance and fire safety performance.

7.1.8.6 For the joint type shown in Figure 4 c), compressed sheet composition gaskets suitable for the service may be used at design pressures of 2 100 kPa gauge (300 psig) or less. Gaskets shall be non-asbestos and shall be suitable for sealing, exposure resistance and fire safety performance.

7.1.8.7 The width of removable cover plate and removable bonnet gaskets shall be at least 10 mm ($\frac{3}{8}$ in).

7.1.8.8 Gaskets shall be of one piece. Where welds are used they shall meet the following.

- a) Welds in the perimeter portion of the gasket shall be continuous and full-penetration. The cross-section, finish and flatness of these welded areas shall match the remainder of the perimeter gasket.
- b) Welds shall not inhibit the sealing or compression of the perimeter gasket or pass ribs.

7.1.8.9 Tables in Annex A may be consulted for further guidance on gaskets.

7.1.9 Nozzles and other connections

7.1.9.1 Flanges shall be in accordance with the pressure design code unless otherwise specified by purchaser.

7.1.9.2 Connections of nominal size DN 32 (NPS 1¹/₄), DN 65 (NPS 2¹/₂), DN 90 (NPS 3¹/₂), DN 125 (NPS 5) or less than DN 20 (NPS 3/4) shall not be used.

7.1.9.3 Connections DN 40 (NPS 1¹/₂) and larger shall be flanged.

7.1.9.4 In hydrogen service sour, or wet hydrogen sulfide service, all connections shall be flanged. Slip-on and lap joint flanges shall not be used.

7.1.9.5 If design conditions require the equivalent of PN 150 (ASME Class 900) or higher flange ratings, all connections shall be flanged.

7.1.9.6 The nominal thickness of the nozzle neck, of carbon steel and low-alloy steel flanged connections shall not be less than specified in Table 3.

Table 3 — Minimum nozzle neck nominal thickness

Pipe size DN (NPS)	Nozzle neck thickness mm (in)
20 (3/4)	5,56 (0,219)
25 (1)	6,35 (0,250)
40 (1 1/2)	7,14 (0,281)
50 (2)	8,74 (0,344)
80 (3)	11,13 (0,438)
100 (4)	13,49 (0,531)
150 (6)	10,97 (0,432)
200 (8)	12,70 (0,500)
250 (10)	15,09 (0,594)
300 (12)	17,48 (0,688)
NOTE The data in this table are taken from ASME B36.10M, using schedule 160 for sizes up to DN 100 (NPS 4) and schedule 80 for the larger sizes.	

- **7.1.9.7** The facing of process flanges shall be in a horizontal plane unless another arrangement is specified by the purchaser.

7.1.9.8 Flanged connections shall be one of the following types:

- a forged or centrifugally cast, integrally flanged welding neck;
- a pipe welded to a forged or centrifugally cast welding neck flange;
- a seamless transition piece attached to a forged or centrifugally cast welding neck flange;
- a fabricated transition (e.g. nozzle necks that are fabricated by rolling and welding of plate), if agreed by the purchaser;

- e) a casting, if agreed by purchaser;
- f) a lap joint stub-in (except for carbon steel and low-alloy), if agreed by purchaser.

7.1.9.9 If a transition is used, stay bars, greater header thickness or greater nozzle thickness can be required to provide adequate mechanical strength.

7.1.9.10 Threaded connections shall be not less than DN 25 (NPS 1), except that pressure gauge connections shall be not less than DN 20 (NPS $\frac{3}{4}$). This includes auxiliary connections such as vents, drains, instrument connections and chemical cleaning connections.

7.1.9.11 Threaded connections shall be one of the following types and shall comply with the pressure design code:

- a) forged steel full-coupling threaded one end only, with a suitable rating (e.g. ASME B16.11, class 6 000);
- b) forged steel fitting with integral reinforcement;
- c) tapped holes for vent and drain connections, where header plate thickness permits;
- d) equivalent boss connection.

7.1.9.12 If a thermowell connection is specified, it shall be located in the nozzle unless the nozzle is smaller than DN 100 (NPS 4), in which case the connection shall be located on the header adjacent to the nozzle.

7.1.9.13 If a pressure gauge connection is specified, it shall be located on the nozzle unless the nozzle is smaller than DN 80 (NPS 3), in which case the connection shall be located on the header adjacent to the nozzle.

7.1.9.14 Pipe threads shall be taper pipe threads (e.g. ASME B1.20.1) and shall comply with the pressure design code.

- **7.1.9.15** The size, type and location of chemical cleaning connections, if any, shall be specified by the purchaser.

7.1.9.16 If specified, instrument connections shall be located in at least one inlet and outlet nozzle per bundle, except that none is required in intermediate nozzles of stacked bundles.

7.1.9.17 All threaded piping connections shall be closed with a round-headed solid plug.

7.1.9.18 Flanged auxiliary connections, if any, shall be closed with blind flanges. The gasket and bolting materials shall be suitable for the specified operating conditions.

7.1.9.19 Vent and drain connections shall be provided at high and low points, respectively, on each header. Header nozzles installed at high and low points may serve as vents and drains. Connections serving as vents and drains shall not extend into the header beyond the inside surface.

7.1.9.20 If the header thickness does not permit minimum thread engagement of vent and drain plugs, couplings or built-up bosses shall be installed.

7.1.9.21 Bolts between connecting nozzles of stacked tube bundles shall be removable without moving the bundles.

7.1.10 Maximum allowable moments and forces for nozzles and headers

7.1.10.1 Each nozzle, in its design corroded condition, shall be capable of withstanding the simultaneous application of the moments and forces defined in Figure 6 and Table 4.

7.1.10.2 The design of each fixed or floating header, the design of the connections of fixed headers to side frames, and the design of other support members shall ensure that the simultaneous application (sum) of all nozzle loadings on a single header does not cause any damage. The components of the nozzle loadings on a single header shall not exceed the following values:

M_x	6 100 N·m (4 500 ft · lbf)
M_y	8 130 N·m (6 000 ft · lbf)
M_z	4 070 N·m (3 000 ft · lbf)
F_x	10 010 N (2 250 lbf)
F_y	20 020 (4 500 lbf)
F_z	16 680 (3 750 lbf)

NOTE The application of the moments and forces shown in Table 4 will cause movement that will tend to reduce the loads to the values given above.

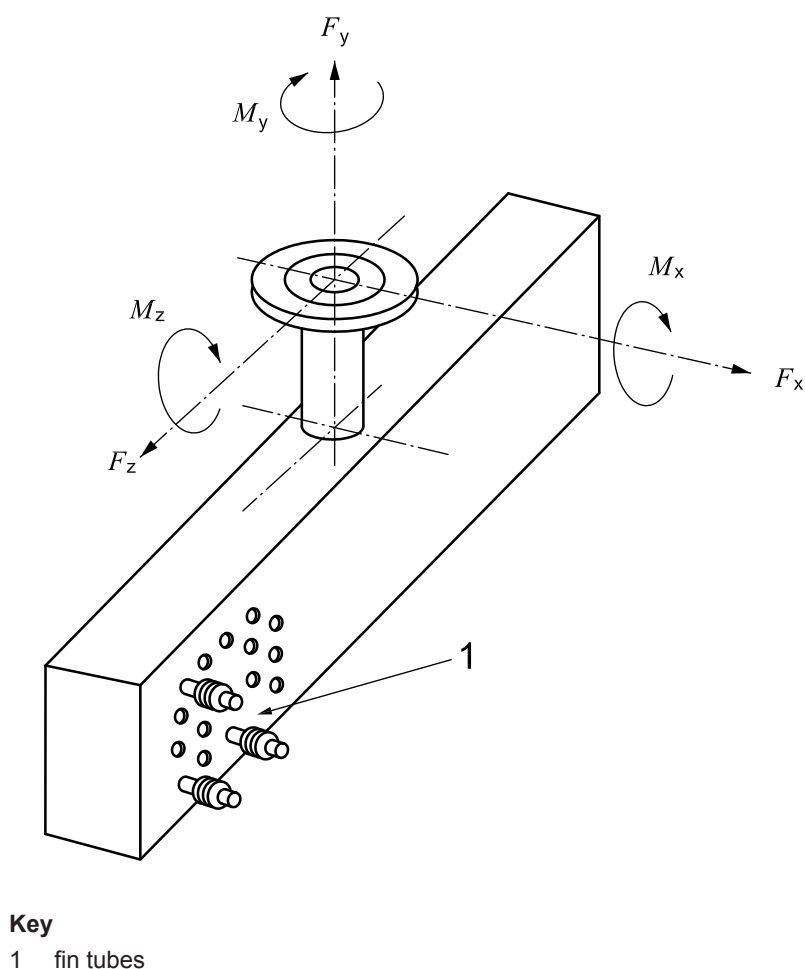


Figure 6 — Nozzle loads

Table 4 — Maximum allowable nozzle loads

Nozzle size DN (NPS)	Moments N·m (ft·lbf)			Forces N (lbf)		
	M_x	M_y	M_z	F_x	F_y	F_z
40 (1½)	110 (80)	150 (110)	110 (80)	670 (150)	1 020 (230)	670 (150)
50 (2)	150 (110)	240 (180)	150 (110)	1 020 (230)	1 330 (300)	1 020 (230)
80 (3)	410 (300)	610 (450)	410 (300)	2 000 (450)	1 690 (380)	2 000 (450)
100 (4)	810 (600)	1 220 (900)	810 (600)	3 340 (750)	2 670 (600)	3 340 (750)
150 (6)	2 140 (1 580)	3 050 (2 250)	1 630 (1 200)	4 000 (900)	5 030 (1 130)	5 030 (1 130)
200 (8)	3 050 (2 250)	6 100 (4 500)	2 240 (1 650)	5 690 (1 280)	13 340 (3 000)	8 010 (1 800)
250 (10)	4 070 (3 000)	6 100 (4 500)	2 550 (1 880)	6 670 (1 500)	13 340 (3 000)	10 010 (2 250)
300 (12)	5 080 (3 750)	6 100 (4 500)	3 050 (2 250)	8 360 (1 880)	13 340 (3 000)	13 340 (3 000)
350 (14)	6 100 (4 500)	7 120 (5 250)	3 570 (2 630)	10 010 (2 250)	16 680 (3 750)	16 680 (3 750)

7.1.10.3 The total of all nozzle loads on one multi-bundle bay shall not exceed three times that allowed for a single header.

7.1.10.4 See 7.1.6.1.3 for further details.

7.1.11 Tubes

7.1.11.1 The outside diameter of cylindrical tubes should be at least 25,4 mm (1 in).

- **7.1.11.2** The maximum tube length shall be as specified by the purchaser.

7.1.11.3 The wall thickness for tubes with an outside diameter of 25,4 mm (1 in) to 51 mm (2 in) shall not be less than that specified in Table 5.

Table 5 — Minimum required wall thickness of tubes

Tube material	Minimum required wall thickness ^a mm (in)
Carbon steel or ferritic low-alloy steel (max. 9 % chromium)	2,11 (0,083)
High-alloy [austenitic, ferritic and austenitic/ferritic (duplex)] steel	1,65 (0,065)
Non-ferrous material	1,65 (0,065)
Titanium	1,24 (0,049)
^a For embedded fin tubes, this thickness shall be measured from the bottom of the groove to the inner wall.	

7.1.11.4 Tubes shall be furnished on either a minimum wall basis or an average wall basis, provided the wall thickness is nowhere less than that specified in 7.1.11.3.

7.1.11.5 Tubes may be finned or unfinned.

7.1.11.6 For a finned tube, the total unfinned length between tubesheets after assembly shall not exceed 1,5 times the thickness of one tubesheet.

- **7.1.11.7** Any finned tube construction shall be a matter of agreement between the purchaser and the vendor. The vendor shall demonstrate that the type of construction furnished is suitable for the intended service conditions (taking into account factors such as metal temperature, cycling, loss of cooling, effect of environment and any specified abnormal operating conditions). The following are descriptions of several types of commonly used finned tube construction.
 - a) Embedded — rectangular cross-section aluminium fin wrapped under tension and mechanically embedded in a groove $0,25 \text{ mm} \pm 0,05 \text{ mm}$ ($0,010 \text{ in} \pm 0,002 \text{ in}$) deep, spirally cut into the outside surface of a tube. Tube wall thickness is measured from the bottom of the groove to the inside diameter of the tube. The fin end at each end of the tube shall be secured to prevent loosening or unravelling of the fins; the vendor shall indicate the method used.
 - b) Extruded (integral) — an aluminium outer tube from which fins have been formed by extrusion, mechanically bonded to an inner tube or liner.
 - c) Overlapped footed — L-shaped aluminium fin wrapped under tension over the outside surface of a tube, with the tube fully covered by the overlapped feet under and between the fins. The fin end at each end of the tube shall be secured to prevent loosening or unravelling of the fins; the vendor shall indicate the method used.
 - d) Footed — L-shaped aluminium fin wrapped under tension over the outside surface of a tube, with the tube fully covered by the feet between the fins. The fin end at each end of the tube shall be secured to prevent loosening or unravelling of the fins; the vendor shall indicate the method used.
 - e) Externally bonded — tubes on which fins are bonded to the outside surface by hot-dip galvanizing, brazing or welding.
 - f) Knurled footed — L-shaped aluminium fin wrapped under tension over the outside surface of a tube, while the foot of the fin is simultaneously pressed into the ribbed outer surface of the tube. The fin end at each end of the tube shall be secured to prevent loosening or unravelling of the fins; the vendor shall indicate the method used.

7.1.11.8 For fins wrapped under tension or embedded, the minimum stock thickness shall be as follows:

- for fin heights less than $12,7 \text{ mm}$ ($1/2 \text{ in}$), the minimum stock thickness shall be $0,35 \text{ mm}$ ($0,014 \text{ in}$);
- for fin heights equal to and above $12,7 \text{ mm}$ ($1/2 \text{ in}$), the minimum stock thickness shall be $0,40 \text{ mm}$ ($0,016 \text{ in}$).

7.1.11.9 Flattening in the bend of U-tubes shall not exceed 10 % of the nominal outside diameter of the tube.

7.1.11.10 The minimum tube wall thickness at the U-bend shall be calculated in accordance with Equation (1).

$$t_b = \frac{t}{1 + \frac{D_o}{4R_m}} \quad (1)$$

where

t_b is the minimum tube wall thickness after bending;

t is the tube wall thickness before bending;

D_o is the tube outside diameter;

R_m is the mean radius of U-bend.

The calculated thickness, t_b , shall not be less than the specified minimum required tube wall thickness as specified in 7.1.11.3.

7.1.11.11 If U-bends are formed from tube materials that are relatively non-work-hardening and are of suitable temper, tube-wall thinning in the bends shall not exceed 17 % of the original tube wall thickness.

- **7.1.11.12** Requirements for heat treatment after bending of the U-tubes shall be specified by the purchaser. The procedures and extent of heat treatment shall be in accordance with the pressure design code and shall be agreed between purchaser and vendor.

7.1.11.13 Elliptical tubes shall not be used unless agreed to by the purchaser. See A.3.3.5 to A.3.3.7.

7.2 Air-side design

7.2.1 General

- **7.2.1.1** Factors such as weather, terrain, mounting, environment and the presence of adjacent structures, buildings and equipment influence the air-side performance of an air-cooled heat exchanger. The purchaser shall supply the vendor with all such environmental data pertinent to the design of the exchanger. These factors shall be taken into account in the air-side design.

7.2.1.2 All air-cooled heat exchangers, whether they are located in a single stand-alone orientation or in a bank of several bays located side by side, require adequate clearance below the fan plenum for forced draft units, or below the tube bundle for induced draft units, to allow an adequate quantity of air to enter the bay and traverse the tube bundle. The velocity of the air approaching the air-cooled heat exchanger (approach velocity) shall not exceed a nominal value of 3,6 m/s (700 ft/min) for forced draft units, or 4 m/s (800 ft/min) for induced draft units at the perimeter of the bay and/or bank. Adjusting the column height is the normal way that the approach velocity is attained on grade-mounted installations. Consideration shall also be given to providing adequate head clearances for mechanical equipment maintenance when adjusting the column heights. See A.3.9.

7.2.1.3 The minimum height above grade for grade-mounted installations shall be calculated in accordance with Equation (2):

$$h = \frac{q_v}{l_p \times k} \quad (2)$$

where

- h is the height above grade to the bottom of the plenum chamber for forced draft type units, or to the bottom of the tube bundle side frames for induced draft type units, expressed in metres (feet);
- q_v is the total actual volumetric flow rate of air that the air-cooled heat exchanger(s) are design to use at design conditions, expressed in actual cubic metres per second (actual cubic feet per minute);
- l_p is the length of the perimeter of the bay or bank, expressed in metres (feet), from which air will be free flowing into the air-cooled heat exchanger(s). [Include only the perimeter of which no air is being blocked or hindered by other structures or bays from entering the air-cooled heat exchanger(s)];
- k is a constant, which is 3,6 m/sec (700 ft/min) for forced draft units and 4,1 m/sec (800 ft/min) for induced draft units.

7.2.1.4 For forced draft units, the kinetic energy of the entering air (ambient air density multiplied by the square of the air approach velocity) shall be less than that of the discharge air exiting the tube bundle (exit air density multiplied by the square of the nominal air discharge velocity).

7.2.1.5 For units with air inlet louvres at the perimeter, the louver area (inside the louver frames) shall be used to determine the approach velocity. Where screens are provided at the perimeter, the area used to calculate the approach velocity shall be discounted by accounting for the area blocked by the screen mesh.

7.2.1.6 The requirement for air flow control shall be as defined by the purchaser on the basis of specific process operation requirements, including the effect of weather.

7.2.1.7 Fan selection at design conditions shall ensure that at rated speed the fan can provide, by an increase in blade angle, a 10 % increase in air flow with a corresponding pressure increase. Since this requirement is to prevent stall and inefficient operation of the fan, it is not necessary that the resulting increased power requirement govern the driver rating.

- **7.2.1.8** If requested by the purchaser, the vendor shall estimate the design exposure temperatures for mechanical components using conventional heat transfer analyses and shall submit the estimate to the purchaser for approval.

For items using air recirculation systems, design exposure temperatures for each operating mode (start-up, normal operation, shutdown, loss of power, stagnated air flow, one fan inoperable, etc.) shall be examined.

7.2.2 Noise control

- **7.2.2.1** For a heat exchanger operating in the specified service with fans operating at design speed and pitch, either or both of the following noise limits shall be specified by the purchaser:
 - a) sound-pressure level (L_p) values per fan at the location designated by the purchaser;
 - b) sound-power level (L_W) values per fan.

NOTE A typical noise data sheet is shown in Annex B.

The vendor shall submit sound-power and sound-pressure levels of the equipment, taking into account relevant information, e.g. inlet shape (type and dimension of bell or cone), obstructions, etc. Reference to fan includes driver, speed reducer, etc.

7.2.2.2 The order of preference for obtaining the required noise data shall be as follows:

- a) actual testing of a representative bay installed either in an environment remote from other noise sources (shop or field tests) or installed in an operating plant;
- b) derivation of noise data by testing similar equipment and adjusting the data for the actual equipment size and operating conditions. Both the measured data and the correction procedure shall be reported.

7.2.2.3 Guidance for determining noise levels is included in Annex E.

7.2.3 Fans and fan hubs

7.2.3.1 Two or more fans aligned in the direction of tube length shall be provided for each bay, except that single-fan arrangements may be used if agreed by the purchaser.

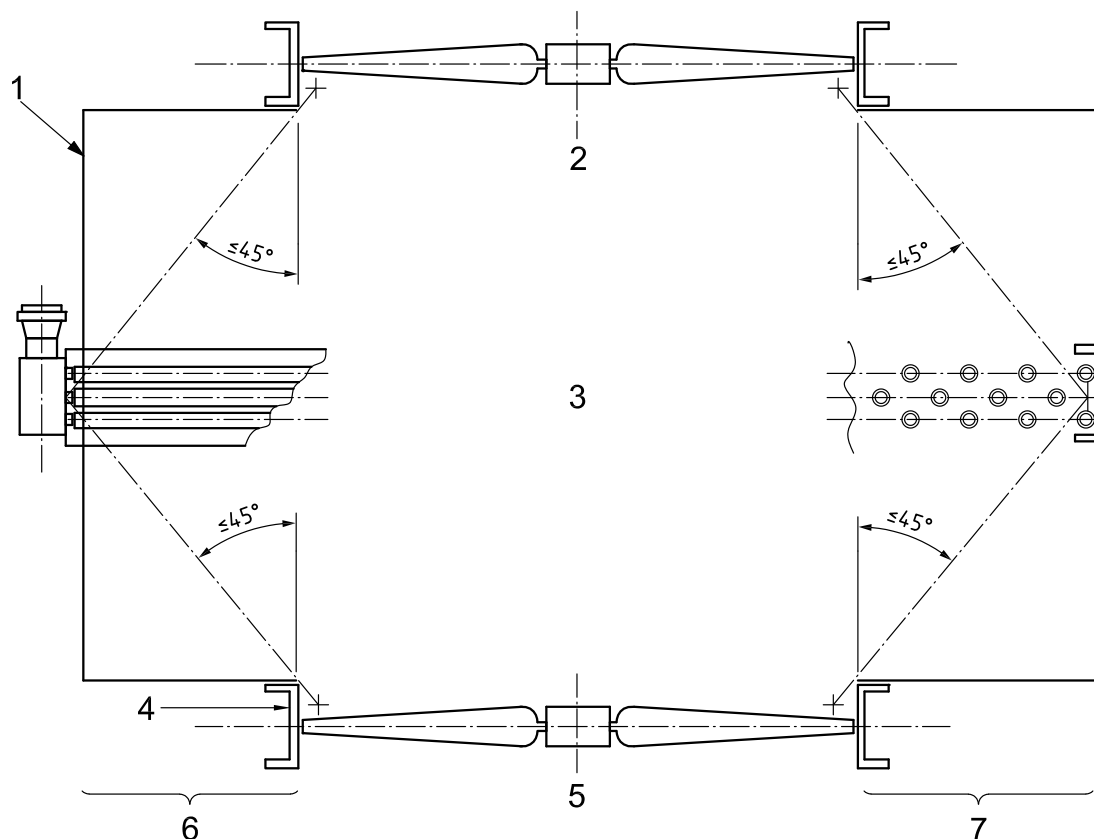
7.2.3.2 Fans shall be of the axial flow type.

7.2.3.3 Each fan shall be sized such that the area occupied by the fan is at least 40 % of the bundle face area served by that fan (the bundle face area being the nominal width of the bundle or bundles multiplied by the nominal tube length).

7.2.3.4 Each fan shall be located such that its dispersion angle shall not exceed 45° at the bundle centreline, as shown in Figure 7.

7.2.3.5 The fan tip speed shall not exceed the maximum value specified by the fan manufacturer for the selected fan type. Fan tip speed shall not exceed 60 m/s (12 000 ft/min) unless approved by the purchaser. In no case shall the fan tip speed exceed 80 m/s (16 000 ft/min). Noise limitations can require lower speeds.

7.2.3.6 The radial clearance between the fan tip and the fan orifice ring shall be as shown in Table 6.



Key

- | | | | |
|---|----------------------|---|----------------|
| 1 | plenum | 5 | forced draught |
| 2 | induced draught | 6 | side |
| 3 | centreline of bundle | 7 | front |
| 4 | fan ring | | |

Figure 7 — Fan dispersion angle

Table 6 — Radial clearances

Fan diameter		Radial clearance mm (in)	
m	(ft)	Minimum	Maximum
$\leq 3,0$	(≤ 9)	6,35 ($^{1/4}$)	12,7 ($^{1/2}$)
$> 3,0$ and $\leq 3,5$	$(> 9$ and $\leq 11)$	6,35 ($^{1/4}$)	15,9 ($^{5/8}$)
$> 3,5$	(> 11)	6,35 ($^{1/4}$)	19,05 ($^{3/4}$)

7.2.3.7 Detachable fan blades shall be moment-balanced against a master blade.

7.2.3.8 Each fan assembly shall be balanced by one of the following means:

- a) dynamic balancing as an assembly;
- b) dynamic balancing of the hub and static moment-balancing of the blades.

7.2.3.9 The fan assembly shall be designed to minimize reverse air flow at the hub.

- **7.2.3.10** For fans having a diameter larger than 1,5 m (5 ft), individual fan blades shall be manually adjustable for varying blade pitch. The use of automatic control for varying the blade pitch shall be as specified by the purchaser.

7.2.3.11 Fans equipped for pneumatically actuated, automatically controlled pitch adjustment of blades shall comply with the following.

- a) If a single controller operates more than one actuator, the purchaser shall provide an isolating valve in the control signal line for each actuator, to allow maintenance.
- b) The pneumatic actuator may be equipped with a positioner or a bias relay.
- c) If provided, the positioner or bias relay shall be designed to operate on a 20 kPa to 100 kPa gauge (3 psig to 15 psig) pneumatic control signal. Each change in the control signal shall result in a corresponding change in the fan blade pitch. The operating range of the positioner shall be adjusted so that the maximum pitch obtained is equal to the selected design blade angle setting. The fan manufacturer shall set maximum and minimum blade pitch limit stops. Unless otherwise specified by the purchaser, the minimum blade pitch limit shall result in an essentially zero air flow.
- d) The vendor shall furnish a flexible tubing connection approximately 300 mm (12 in) long for connecting to the purchaser's control-air line. The tubing shall connect to a rigid steel or alloy pipe or tube that terminates outside the fan enclosure. A terminal fitting for connection to the purchaser's control-air line shall be DN 8 (NPS $\frac{1}{4}$). Pipe threads shall be taper pipe threads.
- e) The purchaser shall specify the direction of change of the fan pitch with loss of control-air pressure.

7.2.3.12 Hub and fan assemblies with automatically controllable pitch adjustment employing lubricated joints shall be designed to minimize lubrication maintenance through the use of bearings not requiring periodic re-lubrication.

7.2.3.13 The fan characteristic performance curve shall relate static or total pressure, rate of flow, blade pitch and fan input shaft power, for dry-air standard conditions as stated in Table 7. The operating point and power for the specified design conditions shall be shown on the fan characteristic performance curve.

Table 7 — Dry-air standard conditions

Dry-bulb temperature	21,1 °C (70 °F)
Pressure	101,3 kPa (29,92 in of mercury)
Density	1,2 kg/m ³ (0,075 lb/ft ³)

7.2.3.14 The natural frequency of the fan or fan components shall not be within 10 % of the blade-pass frequency. Blade-pass frequency (in passes per second) equals the number of blades multiplied by the fan speed (in revolutions per second). Slipping drive belts, low power supply voltage or variable fan-speed control operation cause fan speeds lower than design values; if the blade pass frequency exceeds the natural frequency of the fan or component, the effect of such operation shall be evaluated.

7.2.3.15 No materials (fan blades, hubs, blade retainers and any elastomeric material, etc.) shall be exposed to temperatures above the manufacturer's recommended operating limit, regardless of whether the fan is at rest or in operation.

7.2.3.16 The fan design for the exchanger shall take into account the additional pressure drop associated with the air flowing across insect screens and lint screens, plus an additional allowance for fouling that takes place on the screens. The estimated additional fouling pressure drop component shall be equal to two (2) times the clean pressure drop through the screens. The pressure drop from air flowing across hail screens shall also be taken into account, although it is not necessary to add additional fouling pressure drop due to the location of the hail screens.

7.2.4 Fan shafts and bearings

7.2.4.1 Anti-friction shaft bearings shall have a calculated rating life, L_{10} , of 50 000 h at maximum load and speed in accordance with ISO 281 and/or ISO 76, where L_{10} is the number of hours at rated bearing load and speed that 90 % of a group of identical bearings will complete or exceed before the first evidence of failure.

7.2.4.2 The bearing design shall incorporate seals to prevent loss of lubricant and entry of foreign materials.

7.2.4.3 The fan shaft diameter shall suit the bearings. Bearings shall be sized in accordance with 7.2.4.1.

7.2.4.4 Fan shaft stresses shall not exceed the values given in AGMA 6001.

7.2.4.5 Fan shafts shall have key seats and fits in accordance with ISO 2491 and ISO 286 (all parts) (tolerance N8).

7.2.4.6 Fan bearing exposure temperatures above 130 °C (260 °F) require one or more special features such as high-temperature seals, heat stabilization, retainers or modified internal clearances. Lubricants shall be suitable for the design exposure temperature plus any temperature due to friction and loading.

7.2.5 Lubrication facilities

Connections shall be provided outside the fan guards to permit grease lubrication of fan shaft bearings without shutdown of the equipment. Stainless steel tubing with an outside diameter of at least 6 mm ($\frac{1}{4}$ in) shall be used for grease lines. The connections shall be accessible from grade or service platforms. The length of the grease lines should be minimized.

7.2.6 Fan guards

7.2.6.1 Removable steel fan guards shall be furnished on forced-draught exchangers.

7.2.6.2 The materials of fan blades and fan guards shall be a non-sparking combination.

7.2.6.3 Flattened expanded metal for fan guards shall not exceed 50 mm (2 in) nominal mesh size.

7.2.6.4 The minimum thickness of expanded metal mesh shall be as shown in Table 8.

Table 8 — Minimum thickness of expanded metal fan guard mesh

Nominal size mm (in)	Minimum thickness mm (in)
40 ($1\frac{1}{2}$)	2 (0,070)
50 (2)	3 (0,110)

7.2.6.5 The openings in woven or welded mesh for fan guards shall not exceed an average area of 2 600 mm² (4 in²) if the wire spacing in both directions exceeds 25 mm (1 in).

7.2.6.6 The thickness of wire for welded or woven mesh shall be at least 2,77 mm (12 BWG; 0,109 in).

NOTE BWG is Birmingham Wire Gauge.

7.2.6.7 Fan guards shall be designed with stiffening members so that a concentrated load of 1 000 N (200 lbf) on any 0,1 m² (1 ft²) shall not cause fastener failure or stiffener deflection greater than $L/90$, where L is the length of the span between points of support.

7.2.6.8 The distance from the fan guard to the fan blade at its maximum operating pitch shall be at least 150 mm (6 in) or six times the smaller of the opening dimensions, whichever is the lesser.

7.2.6.9 Gaps between the fan guard and equipment or between sections of the fan guard shall not exceed 12 mm ($1/2$ in).

7.2.7 Drivers

7.2.7.1 General

- **7.2.7.1.1** The purchaser shall specify the type of drive system and the vendor's scope of supply.

7.2.7.1.2 For electric motor drivers, the rated shaft power available at the motor shaft shall be the greater of the terms on the right sides of the following expressions.

$$P_{dr} \geq 1,05 (P_{f1}/E_m)$$

$$P_{dr} \geq 1,10 (P_{f2})$$

where

P_{dr} is driver rated shaft power;

P_{f1} is fan shaft power operating at specified minimum design temperature with blade angle set for design dry-bulb temperature;

E_m is mechanical efficiency of separate power transmissions;

P_{f2} is fan shaft power operating at design dry-bulb temperature.

These requirements apply to fixed-pitch, variable-pitch and variable-speed fans unless otherwise specified.

7.2.7.2 Electric motor drivers

- **7.2.7.2.1** Electric motors shall be three-phase, totally enclosed, fan-cooled motors suitable for service in petrochemical installations and capable of full-voltage starting, full-phase inversion, continuous duty and designed for an 80 °C (140 °F) temperature rise over 40 °C (104 °F) ambient temperature at nameplate rating. The purchaser shall specify the voltage and frequency, the applicable motor specification, the hazardous area classification, the temperature classification and the insulation class.

7.2.7.2.2 The motor manufacturer shall be advised that the motor is intended for air-cooled heat exchanger service and operation outdoors, unprotected against the weather. If the motor operates vertically, the motor manufacturer shall verify in writing that the motor is suitable for vertical operation, either shaft up or shaft down.

7.2.7.2.3 Unless otherwise agreed by the purchaser, motor frames shall be of cast steel or corrosion-resistant cast iron, with integrally cast support feet.

7.2.7.2.4 The motor design loading shall exclude the service factor allowance.

7.2.7.2.5 Motors shall have grease-lubricated bearings designed for an L_{10} life of at least 40 000 h under continuous duty at rated load and speed (see 7.2.4.1 for the definition of L_{10}). If the motor is mounted vertically, the bearing lubrication system and seals shall be suitable for a vertically mounted motor.

7.2.7.2.6 If the motor is mounted in the shaft-up position, the belt sheave shall be designed as a shield to prevent water from accumulating and being directed down the motor shaft while the motor is either idle or running. Alternatively, an external conical slinger may be fitted to the shaft to prevent water from entering the housing along the shaft.

7.2.7.2.7 Motors shall have drains at the lowest point of the frame as mounted on the air-cooled heat exchanger.

7.2.7.2.8 Standard motors are designed for 40 °C (104 °F) ambient temperature and altitudes not exceeding 1 000 m (3 280 ft). Higher temperatures and/or altitudes (resulting in reduced air density) can require improved insulation or an increase in motor frame size. If it is required that the motor be suitable for service exceeding the standard conditions, the motor manufacturer shall be notified.

- **7.2.7.2.9** If specified by the purchaser, a self-actuating braking device shall be installed to prevent reverse rotation of an idle fan.

7.2.7.3 Variable-speed drive systems

- Requirements for variable-speed drive systems (VSDD) shall be agreed between the purchaser and the vendor. This shall include the range of speeds required.

7.2.8 Couplings and power transmissions

7.2.8.1 General

7.2.8.1.1 Bushings and couplings shall be either split taper or cylindrical fit and shall be keyed.

7.2.8.1.2 Power transmission components shall have a rated power for continuous service that is at least equal to the rated power of the actual driver multiplied by the component service factor.

7.2.8.1.3 Fan shaft and gear shaft couplings shall be the non-lubricated type and shall have a minimum service factor of 1,5.

7.2.8.1.4 Exposed moving parts shall have guards in accordance with 7.2.8.4.

7.2.8.1.5 Figure 8 shows typical drive arrangements.

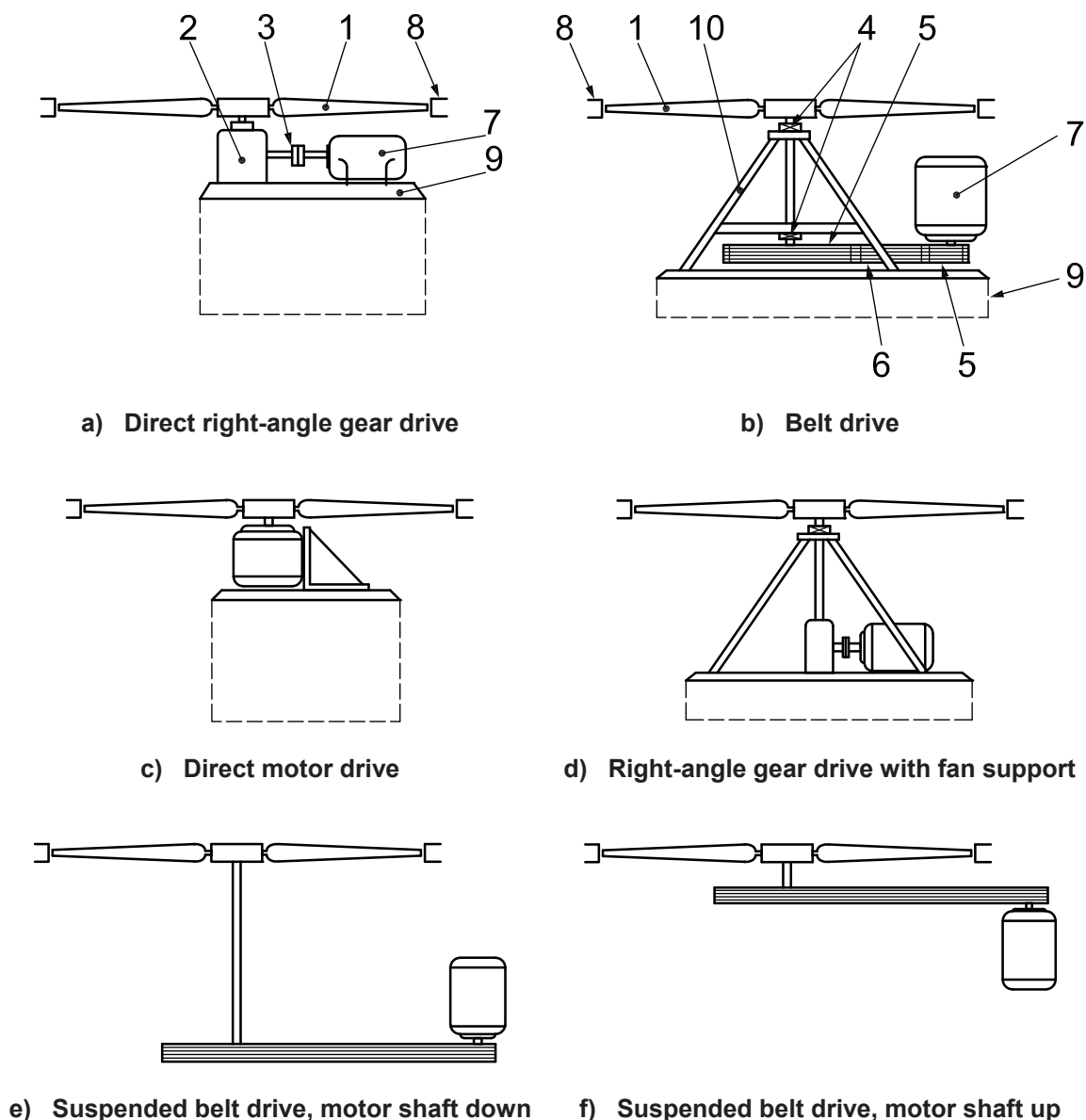


Figure 8 — Typical drive arrangements

7.2.8.2 Belt drives

7.2.8.2.1 Belt drives shall be either conventional V-belts or high-torque type positive-drive belts.

7.2.8.2.2 Belt drives in a heated air stream (such as top-mounted drives) shall not be used unless approved by the purchaser. If so approved, the belt design temperature shall take into account the maximum air temperature near the belt (or the maximum belt temperature possible due to radiation) under all conditions; decreased fan efficiency shall also be taken into account. The vendor shall indicate how the driver is suspended; the driver should not be located in the heated air stream (see also 7.2.7.2.8 and 7.2.8.2.13).

7.2.8.2.3 Belt drives shall be provided with guards in accordance with 7.2.8.4.

7.2.8.2.4 Belt drives shall be provided with jack screws or an equivalent means of initial belt-tensioning and/or re-tensioning.

7.2.8.2.5 V-belt drives shall be in accordance with ISO 1081, ISO 4183, ISO 4184, ISO 5287, ISO 5290 and/or ISO 9563 as applicable.

7.2.8.2.6 V-belts shall be either matched sets of individual belts or a multiple-belt section formed by joining a matched set of individual belts.

7.2.8.2.7 High-torque type positive-drive belts may be either one belt or a pair of matched belts.

7.2.8.2.8 V-belts shall have a minimum service factor of 1,4 based on driver rated power.

7.2.8.2.9 High-torque type positive-drive belts shall have a minimum service factor of 1,8 based on driver-rated power.

7.2.8.2.10 V-belt drive assemblies suspended from the structure may be used with motor drivers rated not higher than 30 kW (40 hp).

7.2.8.2.11 High-torque type positive-drive-belt drive assemblies suspended from the structure may be used with motor drivers rated not higher than 45 kW (60 hp).

7.2.8.2.12 The drive-belt jacket shall be oil resistant.

7.2.8.2.13 Standard drive-belt materials are limited to an exposure temperature of 60 °C (140 °F).

7.2.8.3 Gear drives

7.2.8.3.1 Electric motors rated higher than 45 kW (60 hp) shall use gear drives; smaller motors may use gear drives.

7.2.8.3.2 Gear drives for electric motors rated not higher than 45 kW (60 hp) may be suspended from the structure.

7.2.8.3.3 Gears shall be of the spiral bevel type. They shall have a minimum service factor of 2,0 in accordance with ANSI/AGMA 6010.

7.2.8.3.4 Top-mounted gear drives shall not be used.

7.2.8.3.5 Gear boxes shall be provided with an external oil level indicator visible from the maintenance platform.

7.2.8.4 Mechanical power transmission guards

7.2.8.4.1 Guards shall be provided for moving components.

7.2.8.4.2 Guards shall be constructed to allow ready access for maintenance of the equipment.

7.2.8.4.3 Gaps between guards and equipment shall not exceed 12 mm ($\frac{1}{2}$ in).

7.2.9 Vibration cut-out switches

- **7.2.9.1** One readily accessible, double-throw, two-contact vibration cut-out switch shall be provided for each fan driver unit if specified by the purchaser.

7.2.9.2 Vibration cut-out switches shall be of the manual, externally reset type not requiring dismantling of the switch for resetting and shall have sensitivity adjustment.

7.2.10 Louvres

7.2.10.1 All requirements in 7.2.10 apply to both parallel- and opposed-action louvres, unless otherwise specified.

7.2.10.2 The thickness of louver blades manufactured from plain sheets shall be at least 1,5 mm (16 gauge USS; 0,060 in) for carbon steel and 2,3 mm (13 gauge USS; 0,090 in) for aluminium. The thickness of extruded hollow-shaped aluminium blades shall be at least 1,5 mm (16 gauge USS; 0,060 in).

7.2.10.3 Frames of carbon steel shall be at least 3,5 mm (10 gauge USS; 0,135 in) thick; frames of aluminium shall be at least 4 mm (0,160 in) thick.

7.2.10.4 The unsupported louver blade length shall not exceed 2,1 m (7 ft).

7.2.10.5 The deflections of louver blades and side frames shall not exceed the values given in Table 9.

Table 9 — Maximum allowable louver deflection

Louver components	Maximum deflection
Louver blades in closed position with design load of 2 000 N/m ² (40 lb/ft ²)	$L/180$
Louver side frames with uniform design load of 1 000 N/m ² (20 lb/ft ²)	$L/360$
<i>L</i> designates the length of the span between points of support.	

7.2.10.6 The deflection of louver blades and side frames shall be evaluated at a metal temperature equal to the higher of the following:

- a) maximum process inlet temperature less 30 °C (50 °F);
- b) specified air inlet dry-bulb temperature.

7.2.10.7 The gap between the louver blade and the frame at the header ends shall not exceed 6 mm ($1/4$ in).

7.2.10.8 The gap between the louver blades and the frame at the louver sides shall not exceed 3 mm ($1/8$ in).

7.2.10.9 Louver blade pivot pins shall be designed for their load but, in any case, shall be at least 10 mm ($3/8$ in) in diameter.

7.2.10.10 Bearings designed for exposure temperature in accordance with 7.2.1.4 shall be provided at all pivot points, including control arm, torque rod and blade pivot pins. Bearings shall not require lubrication. The exposure temperature shall not exceed 150 °C (300 °F) for polytetrafluoroethylene (PTFE) base composite bearing material in accordance with 8.4.2. Higher-temperature bearing materials are available but may be used only with the approval of the purchaser.

7.2.10.11 Louver linkages shall be designed so that equal movement of all louver blades results from a change of actuator position. The maximum allowable deviation shall be 3 mm ($1/8$ in), measured as a gap between any two blades with louver actuator in the fully closed position. The means of transmitting force between the louver actuator and the blades shall be adequate to withstand, without damage, the maximum possible force that can be applied by the actuator in any blade position and in either direction.

7.2.10.12 Actuation of louvre sections shall require a torque of not more than 7 N·m for each square metre (6 in-lbf for each square foot) of face area to achieve full travel. The handling force to operate the louvres shall not exceed 250 N (56 lbf).

7.2.10.13 The travel of louvre blades from fully closed to fully open shall be at least 70°.

7.2.10.14 All shaft connections shall be attached at adjustable linkage points by keys, splines or equivalent positive methods. Set-screw connections shall not be used.

7.2.10.15 If used for automatic control, louvre actuators shall be designed to operate with a 20 kPa to 100 kPa gauge (3 psig to 15 psig) pneumatic control signal. If supplied with design motive-air pressure, actuators shall be sized to supply at least 150 % of the necessary force for full-range louvre blade travel. Design motive-air pressure shall be 410 kPa gauge (60 psig) unless otherwise specified.

7.2.10.16 A positioner shall be provided at each actuator unless otherwise specified.

7.2.10.17 If a single controller operates more than one actuator, the purchaser shall provide an isolating valve in the signal line for each actuator to allow maintenance.

7.2.10.18 The location of the actuator and positioner assembly shall not interfere with access to the header, and both shall be readily accessible for maintenance from a service platform (if available). The assembly shall not be in the hot-air stream if the exit air temperature at any condition exceeds 70 °C (160 °F). Alternative materials shall be selected for higher exposure temperatures.

- **7.2.10.19** The louvre position upon loss of control-air pressure shall be specified by the purchaser.

7.2.10.20 All louvres not automatically or otherwise remotely operated shall be provided with extensions or chains to permit manual operation from grade or platform, except that extensions or chains shall not be used if longer than 6 m (20 ft). Handles for manual operators shall not project into walkways or access ways in any operating position.

7.2.10.21 A locking device shall be provided for manual operators to maintain louvre position. Set-screw or thumb-screw locking devices shall not be used. A means shall be provided to indicate whether the louvres are open or closed.

7.2.10.22 The louvre characteristic performance curve shall relate the percentage of air flow to the angle of the louvre blade.

7.2.10.23 Due to the nature of their design, louvres are vulnerable to damage during handling. Spreader bars and anti-racking procedures should be used. Specific handling instructions shall be included on the louvre assembly drawing and shall be marked on the louvre at a lift point.

7.2.10.24 Pin-type retainers shall be used to hold manual control levers of louvres in a set position; butterfly-type locking nuts shall not be used.

7.2.10.25 All linkage joints shall be through-bolted or pinned; friction-type joints shall not be used. The bolting or pinning shall be done after final linkage adjustment.

7.2.11 Screens

7.2.11.1 General

- The purchaser shall specify if screens are required and, if so, shall specify the type (hail screens, insect and/or lint screens).

7.2.11.2 Insect/lint screens

7.2.11.2.1 The purchaser shall approve the screen location and design. In general, it is desirable to locate the screens for low air velocity at the exchanger periphery, normally located on the columns below the tube bundle or plenum chamber.

7.2.11.2.2 Screens shall be removable for cleaning, maintenance and off-season storage. They should be sized to facilitate ease of handling.

7.2.11.2.3 Screen mesh shall be wire cloth. The mesh size shall be number 8 for galvanized or number 16 for stainless steel. Other materials may be used if agreed with the purchaser.

NOTE Mesh number is openings per linear inch, e.g. number 8 has 8 openings per linear inch which is 315 openings per metre.

7.2.11.3 Hail screens

7.2.11.3.1 In forced draft units, hail screens, if specified, shall be located directly above the tubes in the tube bundle and shall cover at least the finned portion of the tubes. In induced draft units, hail screens, if specified, shall be located above the fan in the fan ring.

7.2.11.3.2 Screens shall be either lightweight galvanized grating or galvanized wire cloth. The mesh size shall be number 8. The wire thickness shall be at least 0,43 mm (27 ASWG; 0,017 in).

NOTE ASWG is American Standard Wire Gauge.

7.3 Structural design

7.3.1 General

- **7.3.1.1** The structural code shall be specified or agreed by the purchaser. Structural steel design, fabrication and erection shall be in accordance with the structural code.
- 7.3.1.2** Bolts for load-bearing members shall be designed and installed in accordance with the structural code.
- 7.3.1.3** Weld-metal design stress shall conform to the structural code.
- 7.3.1.4** Structural members shall be designed without the requirement for field welding.
- 7.3.1.5** For induced-draught exchangers, tube bundles shall be removable without removing the platforms, unless otherwise specified by the purchaser. For forced-draught exchangers, the bundles shall be removable without separately supporting or dismantling the fan, plenum or platforms and without disturbing the structure or adjacent bays.
- 7.3.1.6** Suspended drives shall be attached to the structure by through-bolts to permit dismantling.

7.3.2 Vibration testing

- 7.3.2.1** Structural members shall be designed to minimize vibration. The maximum amplitude of vibration over the design fan-speed range shall be 0,15 mm (0,006 in) from peak to peak, as measured on primary structural members and machinery mountings.
- **7.3.2.2** The purchaser shall specify if a shop test is required to verify compliance with the vibration limits.
- 7.3.2.3** Wind velocity at test conditions shall not exceed 5 m/s (10 mph).

7.3.3 Structural design loads and forces

7.3.3.1 General

The design shall take into account the loads and forces defined in 7.3.3.2 through 7.3.3.13.

7.3.3.2 Dead loads

- Dead loads shall consist of the total mass of the material furnished by the vendor plus the mass of any fireproofing. If fireproofing is being applied, the purchaser shall state the extent and type.

7.3.3.3 Live loads

Live loads shall consist of movable loads (including personnel, portable machinery, tools and equipment) and operating loads in equipment and piping. Design live loads on platforms, columns and walkways (exclusive of loads from piping and equipment in place) shall be as specified in Table 10.

Table 10 — Live loads on platforms, columns and walkways

Structural Component	Average load	Concentrated load
Floor plate or grating	4 900 N/m ² (100 lb/ft ²)	—
Floor framing	2 450 N/m ² (50 lb/ft ²)	2 250 N (500 lb)
Columns and brackets	1 200 N/m ² (25 lb/ft ²)	2 250 N (500 lb)
Ladders and stairways	—	2 500 N (500 lb)

7.3.3.4 Impact loads

The vertical design impact load for lifting devices furnished by the vendor shall be two (2,0) times the mass of the heaviest piece of equipment being lifted. The lateral impact load shall be 0,35 times the mass being lifted.

7.3.3.5 Thermal forces

Thermal forces shall include forces caused by partial or complete anchorage of piping or equipment, sliding or rolling friction of equipment and expansion or contraction of the structure. The purchaser and the vendor shall agree on acceptable thermal forces.

7.3.3.6 Test load

The test load is that due to the additional mass of the water used for testing.

7.3.3.7 Wind load

The wind design load shall be in accordance with the structural code.

7.3.3.8 Earthquake forces

Earthquake design shall be in accordance with the ICC unless otherwise specified.

7.3.3.9 Nozzle loads

Nozzle loads shall include all forces and moments applied to the nozzle face, such as deadweight of pipe, thermal forces, the mass of fluid in the piping, etc. The total magnitude and direction of these forces and moments shall be in accordance with 7.1.10 unless otherwise specified.

7.3.3.10 Fan thrust

Fan thrust shall be based on the maximum thrust. If velocity pressure is not included, then fan thrust shall be based on the static pressure shown on the data sheet multiplied by 1,25.

7.3.3.11 Snow load

- The purchaser shall specify the snow load, if any, to apply to the total air-cooled heat exchanger plot area.

7.3.3.12 Other loads

- Loads, forces and moments other than those described in 7.3.3.3 through 7.3.3.11 that are supported by, or applied to, the air-cooled heat exchanger shall be specified by the purchaser in terms of exact type, location, magnitude and direction. Examples of such loads are special transportation loads, auxiliary pipe supports, ladders and walkways furnished by others, and temporary scaffolding supports. Structural and nozzle loads imposed by movement of the structure or installation (e.g. floating production system) on which the exchanger is mounted shall be specified by the purchaser in terms of the exact type, location, magnitude and direction (e.g. pitch, roll, yaw, heave, surge and sway).

7.3.3.13 Loading combinations

All structural components shall be designed to support combinations of the loads and forces to which they can be subjected during erection, testing or flushing of the equipment or when operating at design conditions. The following combination of loads and forces shall be considered in the design of columns, bracing, anchor bolts and foundations and in checking stability against overturning:

a) erection:

- 1) dead load of the structure, less fireproofing;
- 2) the greater of the following:
 - i) dead load of equipment, less piping,
 - ii) dead load of equipment, less platforms supported by the equipment;
- 3) full wind load or earthquake load, whichever is greater;

b) testing or flushing equipment:

- 1) dead load of the structure, plus fireproofing;
- 2) dead load of equipment, including platforms supported by the equipment;
- 3) nozzle loads;
- 4) test loads;
- 5) wind load of 500 N/m² (10 lbf/ft²);
- 6) applicable live loads from platforms and walkways specified in 7.3.3.3; however, these live loads shall not be included in either the design of anchor bolts or the check for stability against wind or earthquake;

c) operation at design conditions:

- 1) dead load of structure;
- 2) dead load of equipment, including platforms supported by the equipment;

- 3) nozzle loads;
- 4) operating mass of fluid in equipment;
- 5) unbalanced forces from impact;
- 6) applicable live loads specified in 7.3.3.3; however, these live loads shall not be included in either the design of anchor bolts or the check for stability against wind or earthquake;
- 7) full wind load or earthquake load, whichever is greater.

Loading conditions of a special nature shall at all times receive proper consideration. (All loads and forces are additive).

7.3.4 Plenums

7.3.4.1 Figure 9 shows typical plenum arrangements.

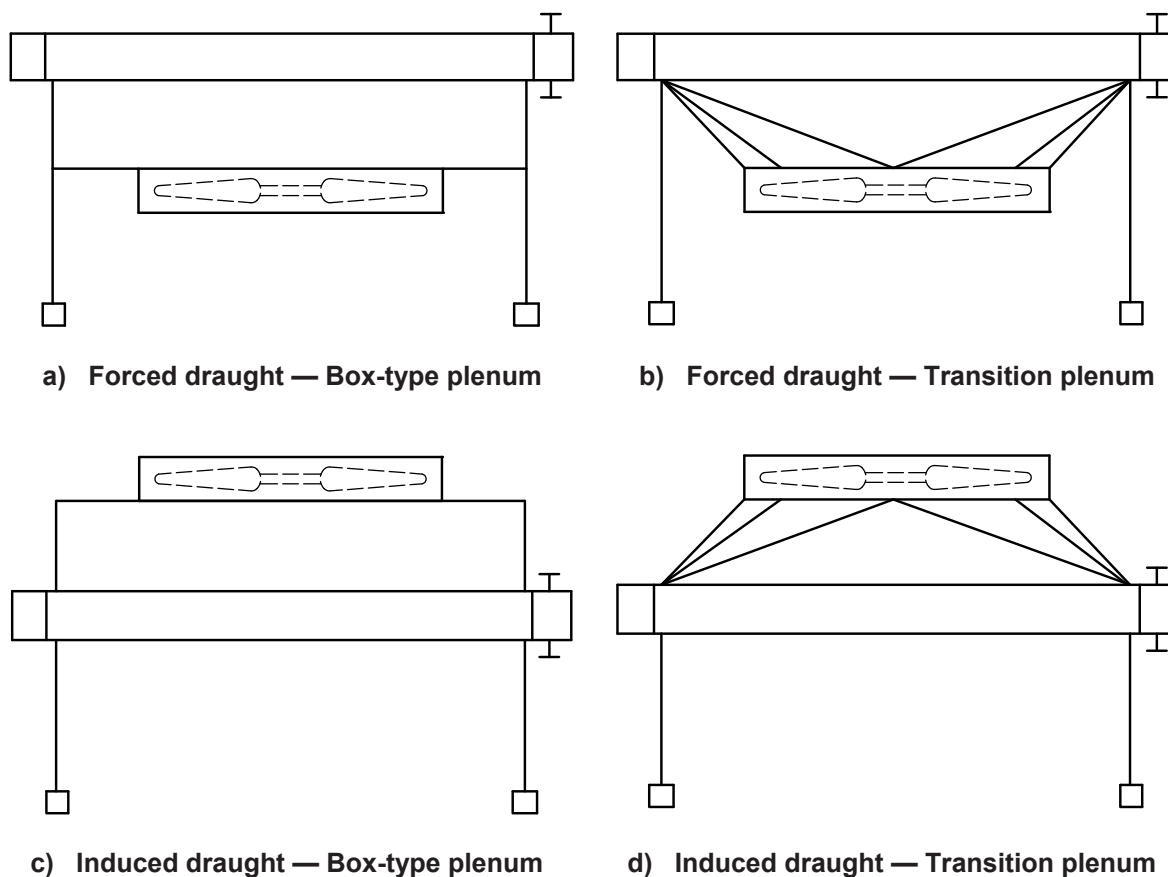


Figure 9 — Typical plenum arrangements

7.3.4.2 Box-type plenums employing panel construction shall be designed to form an integral part of the structure.

7.3.4.3 Bank arrangements for field-assembled units may be designed with common walls between adjacent plenums.

7.3.4.4 The plenums between the fan and the bundle shall be partitioned to prevent recirculation of air from operating fans through non-operating fans.

- **7.3.4.5** Plenum partition requirements for recirculation systems shall be as specified or agreed by the purchaser. See Annex C.

7.3.4.6 The thickness of steel sheet material used in the construction of plenums shall be at least 1,9 mm (14 gauge USS; 0,08 in) flat or 1,5 mm (16 gauge USS; 0,060 in) ribbed.

7.3.4.7 The minimum plenum height shall be obtained from information provided in 7.2.3.4 and Figure 7.

7.3.4.8 Fan decks shall be designed for a live load of 2 500 N/m² (50 lbf/ft²) with a minimum thickness of 2,7 mm (12 gauge USS; 0,105 in).

7.3.5 Mechanical access facilities

- **7.3.5.1** The number and location of header access platforms, interconnecting walkways and ladders shall be specified by the purchaser.

7.3.5.2 If specified, maintenance platforms shall be provided beneath each drive assembly to provide access for removal and replacement of all drive components.

7.3.5.3 Platforms shall have a clear width of at least 0,75 m (30 in).

7.3.5.4 The floor of the walkways, platforms, etc., shall be grating, expanded metal or a raised-pattern solid plate with drain holes. If raised-pattern steel is used, the thickness shall be at least 6 mm (¹/₄ in). Glass-reinforced plastic (GRP) shall be used if specified by the purchaser.

7.3.5.5 Ladders, railings, toe plates, safety cages, etc., shall be of steel construction or, if specified by the purchaser, another metal or GRP in accordance with local regulations. The following shall apply.

- a) Safety cages shall be provided for ladders over 3 m (10 ft) high.
- b) Chains with safety hooks or safety gates shall be provided across ladder openings at platforms.
- c) Ladders over 2 m (6 ft) high shall provide for side-step access to platforms unless otherwise specified.

7.3.5.6 Header platforms shall be provided with a toe-board on the side next to the exchanger. If the gap between the platform and the exchanger is greater than 150 mm (6 in), a knee rail shall be fitted.

7.3.5.7 If steel pipe railings are not galvanized, they shall be sealed to prevent internal corrosion.

- **7.3.5.8** The purchaser shall specify requirements, if any, for personnel protection against high air-outlet temperatures and hot surfaces.

7.3.6 Lifting devices

7.3.6.1 At least two lifting lugs shall be provided on each side frame of tube bundles and each louvre section side frame. Lifting lugs on side frames of adjacent bundles shall be located so as not to interfere with bundle installation.

7.3.6.2 Two lifting lugs shall be provided on each removable cover plate and each removable bonnet.

7.3.6.3 Solid-forging or plate-type lifting lugs shall be used for tube bundle side frames, louvre side frames, cover plates and bonnets. The opening in the lug shall be at least 40 mm (1¹/₂ in) diameter.

7.3.6.4 Sufficient lifting eyes shall be provided on each driver and gear to allow safe installation and dismantling. A structural member shall be provided with load attachment points for removal and replacement of driver components.

7.3.6.5 Lug or eye design shall be based on a total load equal to twice the weight of the lift.

8 Materials

8.1 General

8.1.1 Materials for pressure components shall be in accordance with the pressure design code.

8.1.2 Cast iron shall not be used for pressure components in flammable, lethal or toxic service.

8.1.3 Structural supports, such as side frames and beams, that are part of the tube bundle and not accessible for maintenance shall be galvanized, unless otherwise specified by the purchaser or not permitted by 8.1.5.

8.1.4 Galvanizing of structural steel shall be in accordance with ISO 1461.

8.1.5 Galvanized materials or zinc-containing paints, etc., shall not be used in direct contact with or directly above exposed austenitic stainless steel or high-nickel alloy pressure components. Alternative coatings and/or materials shall be used.

8.1.6 Combinations of construction materials shall be compatible such that electrolytic (galvanic) cells are minimized.

8.2 Requirements for carbon steel in sour or wet hydrogen sulfide service

8.2.1 Materials shall be supplied in the normalized condition, unless otherwise approved by the purchaser. The acceptability of hot formed material shall be subject to approval of the purchaser.

8.2.2 Pressure-retaining components shall be supplied with a certified material test report (CMTR). The CMTR shall include the unspecified elements chromium (Cr), columbium (Cb) (also known as niobium [Nb]), nickel (Ni), vanadium (V), molybdenum (Mo), and copper (Cu) that are used in the equation to calculate the carbon equivalent (CE) as defined by ISO 15156 (all parts) or NACE MR0103.

- 8.2.3 The maximum allowable carbon equivalent shall be agreed with the purchaser, prior to purchase of materials being used in fabrication. Restrictions on other residual elements and micro-alloying elements may also apply depending on the severity of the service. The purchaser shall specify any such restrictions.

8.3 Headers

8.3.1 External load-bearing parts welded to headers shall be of the same nominal composition as the material to which they are welded.

8.3.2 Welded header pass partitions and stiffeners shall be of the same material type as the header plate.

8.3.3 Tube access header plug material shall be compatible with the header material. Cast iron shall not be used for plug material.

8.3.4 Tube access header plugs of carbon steel bar-stock material or individual forged plugs shall be of a material allowed by the pressure design code (e.g. ASME BPVC II, SA-105).

8.3.5 Precautions should be taken to avoid galling between the plugs and the plug sheet.

8.4 Louvres

8.4.1 Louvre blade pivot pins shall be austenitic stainless steel or UNS A96063 aluminium alloy in the T6 temper condition.

8.4.2 Louvre bearings shall be of either polytetrafluoroethylene (PTFE) base composite material containing at least 20 % fill (exposure temperatures shall be in accordance with 7.2.10.10), or an approved alternative if required for a higher design temperature.

8.4.3 Steel louvre blades and frames shall be galvanized. If mill-galvanized material is used, all cut and punched edges shall be protected by a zinc-rich coating.

8.5 Other components

8.5.1 Fin material shall be aluminium, unless otherwise specified or agreed by the purchaser.

8.5.2 Fan blades shall be of aluminium alloy or GRP, unless otherwise specified.

8.5.3 Plugs for threaded connections, such as vents, drains and instrument connections, shall be of the same material type as the connection.

8.5.4 Plenums, fan decks, partitions, platforms and fan rings shall be of carbon steel unless otherwise specified.

8.5.5 Metal gasket material shall be softer than the gasket contact surface.

8.5.6 Solid metal gaskets for shoulder plugs shall have a Rockwell hardness no greater than HRB 68 for carbon steel or HRB 82 for austenitic stainless steel.

9 Fabrication of tube bundle

9.1 Welding

9.1.1 General

9.1.1.1 Welding procedures and welders shall be qualified in accordance with the pressure design code. Welding shall be performed in accordance with the pressure design code.

9.1.1.2 All pressure-containing header welds and nozzle welds shall have full penetration and full fusion.

9.1.1.3 The root pass of single-side welded joints without backing strips shall be made using gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) or low-hydrogen shielded metal arc welding (SMAW).

9.1.1.4 Enclosed spaces between any welded attachment and the headers shall be vented by a 3 mm ($\frac{1}{8}$ in) diameter drilled hole.

- **9.1.1.5** The purchaser shall specify whether weld procedure qualifications for carbon steel in sour or wet hydrogen sulfide service, including tube to tubesheet welds, shall include a micro-hardness survey performed on a weld cross-section and transverse to the weld centreline. The micro-hardness testing and acceptance criteria shall be in accordance with NACE SP0472 or ISO 15156 (all parts), as applicable. Any additional restrictions on class, grade, residual elements or micro-alloying elements for the qualification test material shall be specified by the purchaser.

9.1.2 Plug headers

9.1.2.1 Partition plates shall be seal-welded to abutting tubesheet and plugsheet plates and shall be welded from both sides; a full-penetration weld joint preparation shall be used. Seal welds on the ends of internal pass partitions plates are excluded from this requirement.

9.1.2.2 If pass partition plates are also used as stiffeners, a full-penetration configuration shall be used and weld joint efficiencies shall be in accordance with the pressure design code.

9.1.3 Removable cover plate and removable bonnet headers

9.1.3.1 Removable cover plate flanges and removable bonnet header flanges shall be installed with full penetration welding.