

Petroleum and natural gas industries — Fired heaters for general refinery service

The European Standard EN ISO 13705:2001 has the status of a
British Standard

ICS 75.180.20

National foreword

This British Standard is the official English language version of EN ISO 13705:2001. It is identical with ISO 13705:2001.

The UK participation in its preparation was entrusted by Technical Committee PSE/17, Materials and equipment for petroleum and natural gas industries, to Subcommittee PSE/17/-/6, Processing equipment and systems for petroleum and natural gas industries, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

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This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 30 January 2002

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English version

Petroleum and natural gas industries - Fired heaters for general refinery service (ISO 13705:2001)

Industries du pétrole et du gaz naturel - Réchauffeurs à brûleurs pour usage général dans les raffineries (ISO 13705:2001)

This European Standard was approved by CEN on 15 December 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

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Foreword

This document (EN ISO 13705:2001) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum 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 2002, and conflicting national standards shall be withdrawn at the latest by June 2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 13705:2001 has been approved by CEN as EN ISO 13705:2001 without any modifications.

INTERNATIONAL STANDARD

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13705

First edition
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Petroleum and natural gas industries — Fired heaters for general refinery service

*Industries du pétrole et du gaz naturel — Réchauffeurs à brûleurs pour
usage général dans les raffineries*



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Foreword

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

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

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

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

International Standard ISO 13705 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Annexes D and E form a normative part of this International Standard. Annexes A, B, C, F, G and H are for information only.

Introduction

This International Standard is based on API standard 560, second edition, September 1995.

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

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

A bullet (●) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on data sheets (see examples in annex A) or stated in the enquiry or purchase order. Decisions should be indicated on a check list (see example in annex B).

Petroleum and natural gas industries — Fired heaters for general refinery service

1 Scope

This International Standard specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing, preparation for shipment, and erection of fired heaters, air preheaters, fans and burners for general refinery service.

2 Normative references

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

ISO 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 13704, *Petroleum and natural gas industries — Calculation of heater-tube thickness in petroleum refineries*

EN 10025¹⁾, *Hot rolled products of non-alloy structural steels — Technical delivery conditions*

AFBMA Standard 9²⁾, *Load ratings and fatigue life for ball bearings*

AMCA 99-2404-78³⁾, *Drive arrangements for centrifugal fans*

AMCA 201, *Fans and systems*

AMCA 210, *Laboratory methods of testing fans for aerodynamic performance rating*

ASME B17.1⁴⁾, *Keys and keyseats*

ASME B31.3, *Process piping*

ASME Boiler and pressure vessel code, Section VIII, *Rules for construction of pressure vessels*

ASTM A 36⁵⁾, *Standard specification for carbon structural steel*

1) European Committee for Standardization (CEN), Rue de Stassart 36, B-1050 Brussels, Belgium.

2) Anti-Friction Bearing Manufacturers Association, 1200 19th Street NW, Suite 300, Washington, DC 20036-2412, USA.

3) Air Movement and Control Association, 30 West University Drive, Arlington Heights, IL 60004, USA.

4) American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10017, USA.

5) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

ASTM A 105, *Standard specification for carbon steel forgings for piping applications*

ASTM A 123, *Standard specification for zinc (hot-dip galvanized) coatings on iron and steel products*

ASTM A 143, *Standard practice for safeguarding against embrittlement of hot-dip galvanized structural steel products and procedure for detecting embrittlement*

ASTM A 153, *Standard specification for zinc coating (hot-dip) on iron and steel hardware*

ASTM A 161, *Standard specification for seamless low-carbon and carbon-molybdenum steel still tubes for refinery service*

ASTM A 181, *Standard specification for carbon steel forgings, for general-purpose piping*

ASTM A 182, *Standard specification for forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts for high-temperature service*

ASTM A 192, *Standard specification for seamless carbon steel boiler tubes for high-pressure service*

ASTM A 193, *Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service*

ASTM A 194, *Standard specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both*

ASTM A 209, *Standard specification for seamless carbon-molybdenum alloy-steel boiler and superheater tubes*

ASTM A 210, *Standard specification for seamless medium-carbon steel boiler and superheater tubes*

ASTM A 213, *Standard specification for seamless ferritic and austenitic alloy-steel boiler, superheater and heat-exchanger tubes*

ASTM A 216, *Standard specification for steel castings, carbon, suitable for fusion welding, for high-temperature service*

ASTM A 217, *Standard specification for steel castings, martensitic stainless and alloy, for pressure-containing parts, suitable for high-temperature service*

ASTM A 234, *Standard specification for piping fittings of wrought carbon steel and alloy steel for moderate and high temperature service*

ASTM A 240, *Standard specification for heat-resisting chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure vessels*

ASTM A 242, *Standard specification for high-strength low-alloy structural steel*

ASTM A 283, *Standard specification for low and intermediate tensile strength carbon steel plates*

ASTM A 297, *Standard specification for steel castings, iron-chromium and iron-chromium-nickel, heat resistant, for general application*

ASTM A 307, *Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength*

ASTM A 320, *Standard specification for alloy steel bolting materials for low-temperature service*

ASTM A 325, *Standard specification for structural bolts, steel, heat treated, 120/105 ksi minimum tensile strength*

ASTM A 351, *Standard specification for castings, austenitic, austenitic-ferritic (duplex), for pressure-containing parts*

ASTM A 384, *Standard practice for safeguarding against warpage and distortion during hot-dip galvanizing of steel assemblies*

- ASTM A 385, *Standard practice for providing high-quality zinc coatings (hot-dip)*
- ASTM A 387, *Standard specification for pressure vessel plates, alloy steel, chromium-molybdenum*
- ASTM A 403, *Standard specification for wrought austenitic stainless steel piping fittings*
- ASTM A 447, *Standard specification for steel castings, chromium-nickel-iron alloy (25-12 class), for high-temperature service*
- ASTM A 560, *Standard specification for castings, chromium-nickel alloy*
- ASTM A 572, *Standard specification for high-strength, low alloy columbium-vanadium structural steel*
- ASTM A 608, *Standard specification for centrifugally cast iron-chromium-nickel high-alloy tubing for pressure application at high temperatures*
- ASTM B 366, *Standard specification for factory-made wrought nickel and nickel alloy fittings*
- ASTM B 407, *Standard specification for nickel-iron-chromium alloy seamless pipe and tube*
- ASTM B 564, *Standard specification for nickel alloy forgings*
- ASTM B 633, *Standard specification for electrodeposited coatings of zinc on iron and steel*
- ASTM C 27, *Standard classification of fireclay and high-alumina refractory brick*
- ASTM C 155, *Standard classification of insulating firebrick*
- ASTM C 332, *Standard specification for lightweight aggregates for insulating concrete*
- ASTM C 401, *Standard classification of alumina and alumina-silicate castable refractories*
- ASTM C 612, *Standard specification for mineral fiber block and board thermal insulation*
- AWS⁶⁾ D1.1, *Structural welding code — Steel*
- AWS D14.6-96, *Specification for welding of rotating elements of equipment*
- MSS SP-55⁷⁾, *Quality standard for steel castings for valves, flanges and fittings, and other piping components — Visual method*
- NFPA 70⁸⁾, *National electrical code*

3 Terms and definitions

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

NOTE Terms and definitions related to centrifugal fans are given in annex E.

3.1

air heater

air preheater

heat transfer apparatus through which combustion air is passed and heated by a medium of higher temperature, such as the combustion products, steam or other fluid

6) American Welding Society, 550 NW Le Jeune Road, Miami, FL 33126, USA.

7) Manufacturers Standardization Society, 127 Park Street NE, Vienna, VA 22180, USA.

8) National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101, USA.

3.2

anchor

tieback

metallic or refractory device that holds the refractory or insulation in place

3.3

arch

flat or sloped portion of the heater radiant section opposite the floor

3.4

atomizer

device used to reduce liquid fuel to a fine mist

3.5

backup layer

refractory layer behind the hot face layer

3.6

balanced draught heater

heater which uses forced-draught fans to supply combustion air and uses induced fans to remove flue gases

3.7

breeching

heater section where flue gases are collected after the last convection coil for transmission to the stack or the outlet ductwork

3.8

bridgewall

gravity wall

wall which separates two adjacent heater zones

3.9

bridgewall temperature

temperature of flue gas leaving the radiant section

3.10

burner

device which introduces fuel and air into a heater at the desired velocities, turbulence and concentration to establish and maintain proper ignition and combustion

NOTE Burners are classified by the type of fuel fired, such as oil, gas, or a combination of gas and oil, which may be designated as "dual fuel" or "combination".

3.11

butterfly damper

single-blade damper which pivots about its centre

3.12

casing

metal plate used to enclose the fired heater

3.13

castable

insulating concrete poured or gunned in place to form a rigid refractory shape or structure

3.14

ceramic fibre

fibrous refractory insulation composed primarily of silica and alumina

NOTE Applicable forms include blanket, board, module, rigidized blanket, and vacuum-formed shapes.

3.15**convection section**

portion of the heater in which the heat is transferred to the tubes primarily by convection

3.16**corbel**

projection from the refractory surface generally used to prevent flue gas bypassing the tubes of the convection section if they are on a staggered pitch

3.17**corrosion allowance**

additional material thickness added to allow for material loss due to corrosion

3.18**corrosion rate**

rate of reduction in the material thickness due to chemical attack from the process fluid or flue gas or both

NOTE Corrosion rate is expressed in millimetres per year (mils per year).

3.19**crossover**

interconnecting piping between any two heater-coil sections

3.20**damper**

device for introducing a variable resistance in order to regulate the flow of flue gas or air

3.21**direct air preheater**

heat exchanger which transfers heat directly between the flue gas and the combustion air

NOTE A regenerative air preheater uses heated rotating elements and a recuperative design uses stationary tubes, plates, or cast iron elements to separate the two heating media.

3.22**draught**

negative pressure (vacuum) of the air and/or flue gas measured at any point in the heater

3.23**draught loss**

pressure drop (including buoyancy effect) through duct conduits or across tubes and equipment in air and flue gas systems

3.24**duct**

conduit for air or flue gas flow

3.25**fuel efficiency**

total heat absorbed divided by the total input of heat derived from the combustion of fuel only (lower heating value basis)

NOTE This definition excludes sensible heat of the fuels and applies to the net amount of heat exported from the unit.

3.26**thermal efficiency**

total heat absorbed divided by the total input of heat derived from the combustion of fuel (h_L) plus sensible heats from air, fuel and any atomizing medium

3.27

erosion

reduction in material thickness due to mechanical attack from a fluid

3.28

excess air

amount of air above the stoichiometric requirement for complete combustion

NOTE Excess air is expressed as a percentage.

3.29

extended surface

heat-transfer surface in the form of fins or studs attached to the heat-absorbing surface

3.30

extension ratio

ratio of total outside exposed surface to the outside surface of the bare tube

3.31

flue gas

gaseous product of combustion including excess air

3.32

forced-draught heater

heater for which combustion air is supplied by a fan or other mechanical means

3.33

fouling allowance

factor to allow for a layer of residue that increases pressure drop

NOTE 1 This residue is usually a build-up of coke or scale on the inner surface of a coil.

NOTE 2 The fouling allowance is used in calculating the fouled pressure drop.

3.34

fouling resistance

factor used to calculate the overall heat transfer coefficient

NOTE The inside fouling resistance is used to calculate the maximum metal temperature for design. The external fouling resistance is used to compensate the loss of performance due to deposits on the external surface of the tubes or extended surface.

3.35

header

return bend

cast or wrought fitting shaped in a 180° bend and used to connect two or more tubes

3.36

header box

internally insulated structural compartment, separated from the flue-gas stream, which is used to enclose a number of headers or manifolds

NOTE Access is afforded by means of hinged doors or removable panels.

3.37

heat absorption

total heat absorbed by the coils, excluding any combustion-air preheat

3.38**average heat flux density**

heat absorbed divided by the exposed heating surface of the coil section

NOTE Average flux density for an extended-surface tube is indicated on a bare surface basis with extension ratio noted.

3.39**maximum heat flux density**

maximum local rate of heat transfer in the coil section

3.40**total heat release**

heat liberated from the specified fuel, using the lower heating value of the fuel

3.41**volumetric heat release**

heat released divided by the net volume of the radiant section, excluding the coils and refractory dividing walls

3.42**higher heating value**

h_H

gross heating value

total heat obtained from the combustion of a specified fuel at 15 °C (60 °F)

3.43**lower heating value**

h_L

net heating value

higher heating value minus the latent heat of vaporization of the water formed by combustion of hydrogen in the fuel

3.44**hot face layer**

refractory layer exposed to the highest temperatures in a multilayer or multicomponent lining

3.45**hot face temperature**

temperature of the refractory surface in contact with the flue gas or heated combustion air

NOTE The hot face temperature is used to determine refractory or insulation thickness and heat transmitted.

3.46**indirect air preheater**

fluid-to-air heat transfer device

NOTE The heat transfer can be accomplished by using a heat-transfer fluid, process stream or utility stream which has been heated by the flue gas or other means. A heat pipe air preheater uses a vaporizing/condensing fluid to transfer heat between the flue gas and air.

3.47**induced-draught heater**

heater which uses a fan to remove flue gases and maintain a negative pressure in the heater to induce combustion air without a forced-draught fan

3.48**jump over**

interconnecting pipework within a heater coil section

3.49

louvre damper

damper consisting of several blades, each of which pivots about its centre and is linked to the other blades for simultaneous operation

3.50

manifold

chamber for the collection and distribution of fluid to or from multiple parallel flow paths

3.51

metal fibre reinforcement

stainless steel needles added to castable for improved toughness and durability

3.52

monolithic lining

single-component lining system

3.53

mortar

refractory material preparation used for laying and bonding refractory bricks

3.54

multicomponent lining

refractory system consisting of two or more layers of different refractory types

NOTE Examples of refractory types are castable and ceramic fibre.

3.55

multilayer lining

refractory system consisting of two or more layers of the same refractory type

3.56

natural-draught heater

heater in which a stack effect induces the combustion air and removes the flue gases

3.57

normal heat release

design heat absorption of the heater divided by the calculated fuel efficiency

3.58

pass

stream

flow circuit consisting of one or more tubes in series

3.59

pilot

small burner that provides ignition energy to light the main burner

3.60

plenum

windbox

chamber surrounding the burners that is used to distribute air to the burners or reduce combustion noise

3.61

plug header

cast return bend provided with one or more openings for the purpose of inspection or mechanical tube cleaning

3.62**pressure design code**

recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME Boiler and Pressure Vessel Code, Section VIII.

3.63**pressure drop**

difference between the inlet and the outlet static pressures between termination points, excluding the static differential head

3.64**primary air**

portion of the total combustion air that first mixes with the fuel

3.65**protective coating**

corrosion-resistant material applied to a metal surface

EXAMPLE Coating on casing plates behind porous refractory materials to protect against sulfur in the flue gases.

3.66**radiant section**

portion of the heater in which heat is transferred to the tubes primarily by radiation

3.67**radiation loss****setting loss**

heat lost to the surroundings from the casing of the heater and the ducts and auxiliary equipment (when heat recovery systems are used)

3.68**secondary air**

air supplied to the fuel to supplement primary air

3.69**setting**

heater casing, brickwork, refractory and insulation, including the tiebacks

3.70**shield section****shock section**

tubes that shield the remaining convection-section tubes from direct radiation

3.71**sootblower**

device used to remove soot or other deposits from heat-absorbing surfaces in the convection section

NOTE Steam is normally the medium used for soot blowing.

3.72**stack**

vertical conduit used to discharge flue gas to the atmosphere

3.73**strake****spoiler**

metal attachment to a stack which can prevent the formation of von Karman vortices that can cause wind-induced vibration

3.74

structural design code

structural design standard specified or agreed by the purchaser

EXAMPLES ICBO Uniform Building Code, ASCE standards, AISC Specification for design, fabrication and erection of structural steel for buildings.

3.75

target wall

re-radiating wall

vertical refractory firebrick wall which is exposed to direct flame impingement on one or both sides

3.76

temperature allowance

number of degrees Celsius (Fahrenheit) to be added to the process fluid temperature to account for flow maldistribution and operating unknowns

NOTE The temperature allowance is added to the calculated maximum tube-metal temperature or the equivalent tube-metal temperature to obtain the design metal temperature

3.77

terminal

flanged or welded connection to or from the coil providing for inlet and outlet of fluids

3.78

tube guide

device used with vertical tubes to restrict horizontal movement while allowing the tube to expand axially

3.79

tube retainer

device used to restrain horizontal radiant tubes from lifting off the intermediate tube supports during operation

3.80

tube support

tube sheet

device used to support tubes

3.81

vapour barrier

metallic foil placed between layers of refractory as a barrier to flue gas flow

4 General

4.1 Precautions

Care shall be exercised when using certain materials in the construction of fired heater components, in particular those where a dust hazard may be experienced. Manufacturer's recommendations and local and national safety requirements shall be followed in all cases.

4.2 Pressure design code

- 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 in this International Standard.

4.3 Local regulations

- The vendor shall comply with the applicable local rules and regulations specified by the purchaser.

4.4 Heater nomenclature

In a fired heater, heat liberated by the combustion of fuels is transferred to fluids contained in tubular coils within an internally insulated enclosure. The type of heater is normally described by the structural configuration, radiant tube coil configuration, and burner arrangement. Some examples of structural configurations are cylindrical, box, cabin and multicell box. Examples of radiant tube coil configurations include vertical, horizontal, helical and arbor. Examples of burner arrangements include upfired, downfired and wallfired. The wallfired arrangement can be further classified as sidewall, endwall and multilevel.

Figure 1 illustrates some typical heater types.

Figure 2 illustrates typical burner arrangements.

Various combinations of Figures 1 and 2 can be used. For example, Figure 1 c) can employ burner arrangements as in Figure 2 a), b) or c) Similarly, Figure 1 d) can employ burner arrangements as in Figure 2 a) or d).

Figure 3 shows typical components. Figures 4, 5 and 6 show typical combustion-air preheat systems.

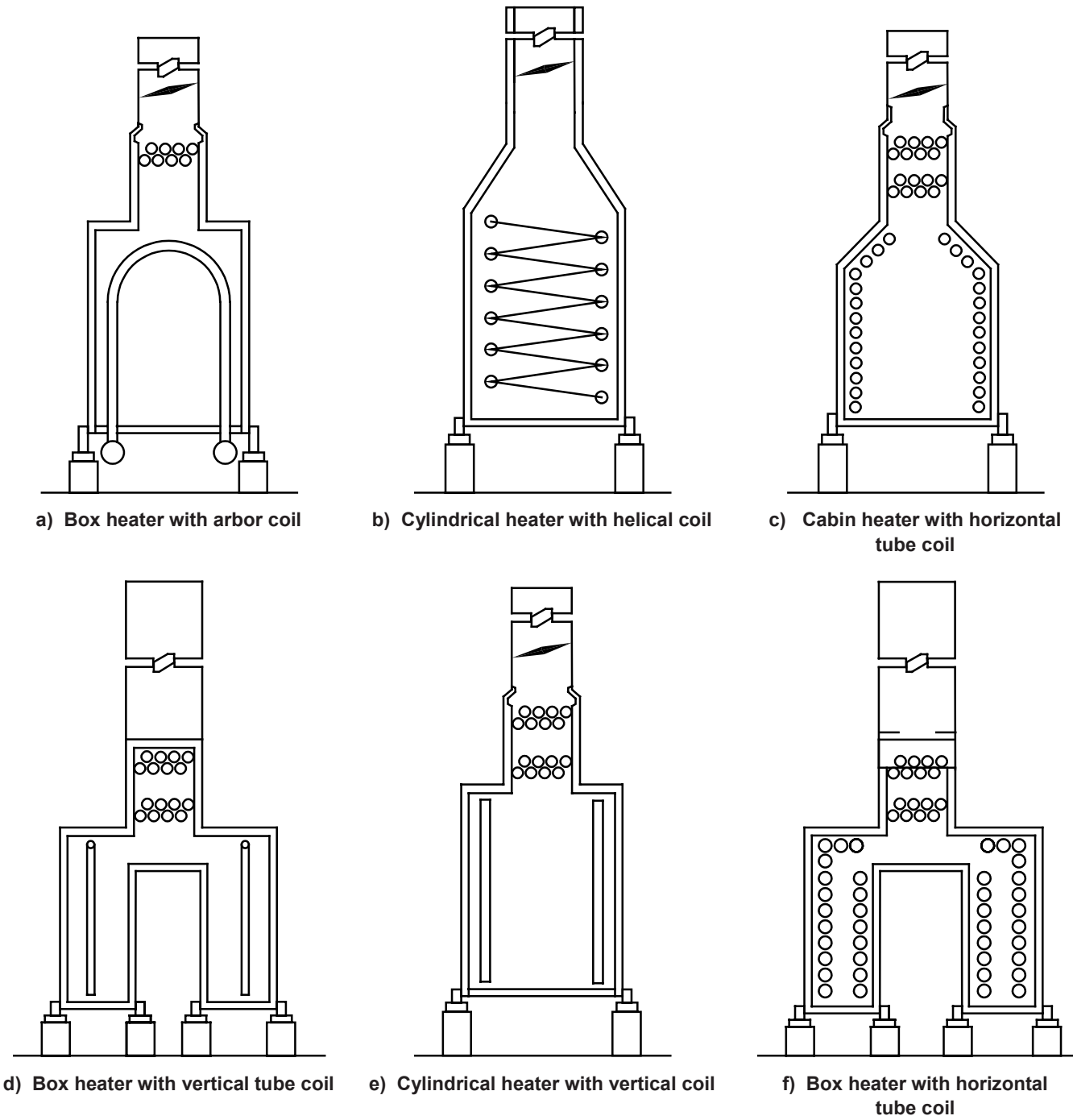
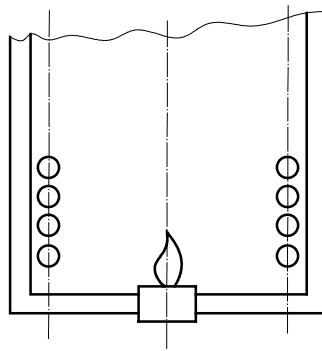
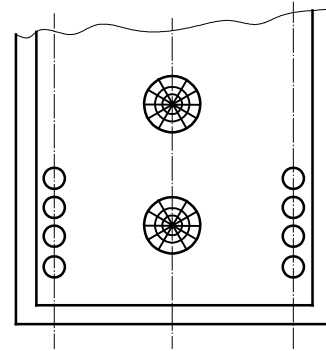


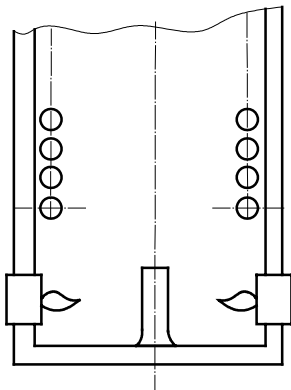
Figure 1 — Typical heater types



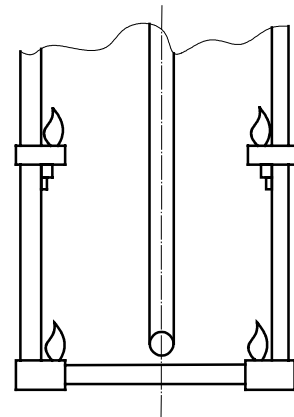
a) Upfired



b) Endwall-fired

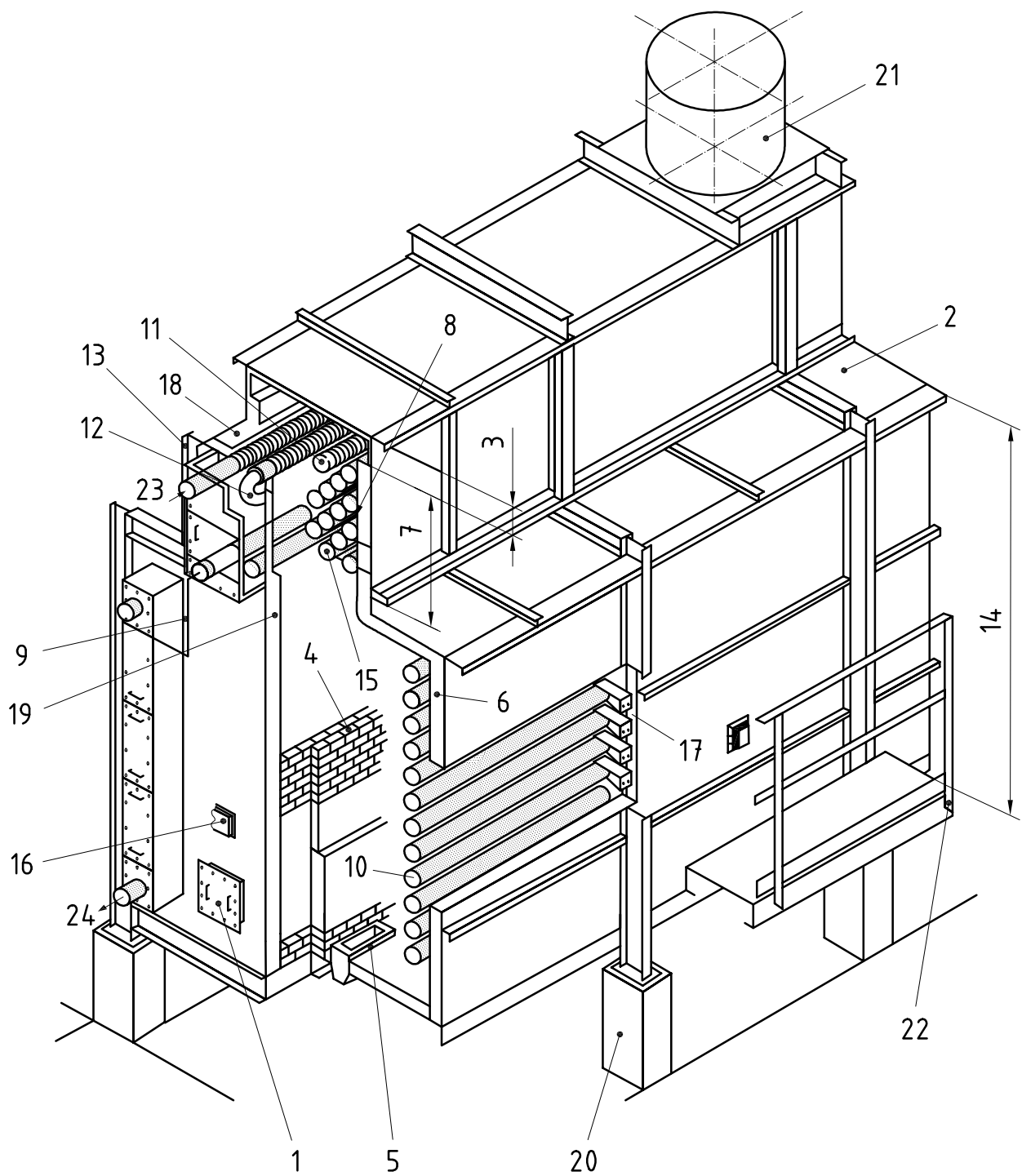


c) Sidewall-fired



d) Sidewall-fired multi-level

Figure 2 — Typical burner arrangements (elevation view)



Key			
1	Access door	7	Convection section
2	Arch	8	Corbel
3	Breeching	9	Crossover
4	Bridgeway	10	Tubes
5	Burner	11	Extended surface
6	Casing	12	Return bend
		13	Header box
		14	Radiant section
		15	Shield section
		16	Observation door
		17	Tube support
		18	Refractory lining
		19	End tube sheet
		20	Pier
		21	Stack/duct
		22	Platform
		23	Process in
		24	Process out

Figure 3 — Heater components

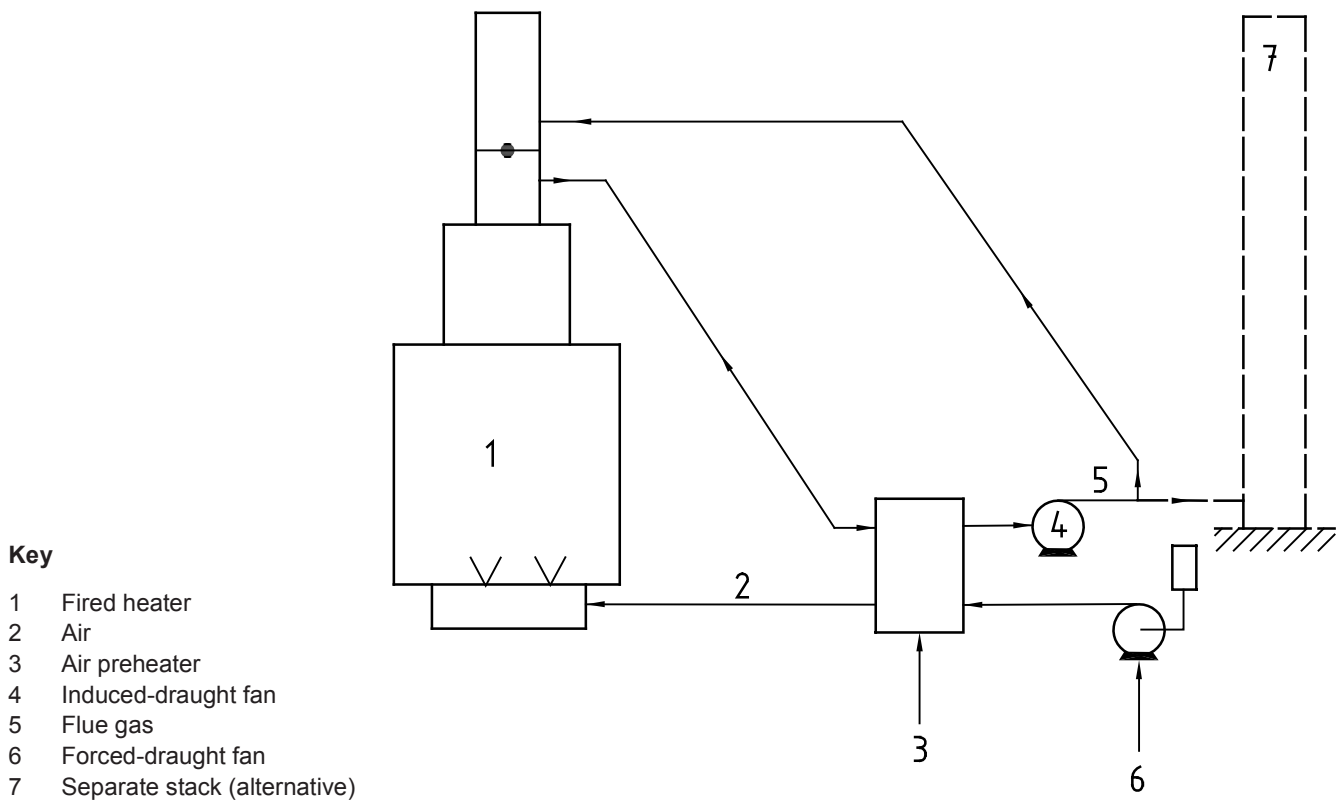


Figure 4 — Air preheat system using regenerative, recuperative or heat pipe unit

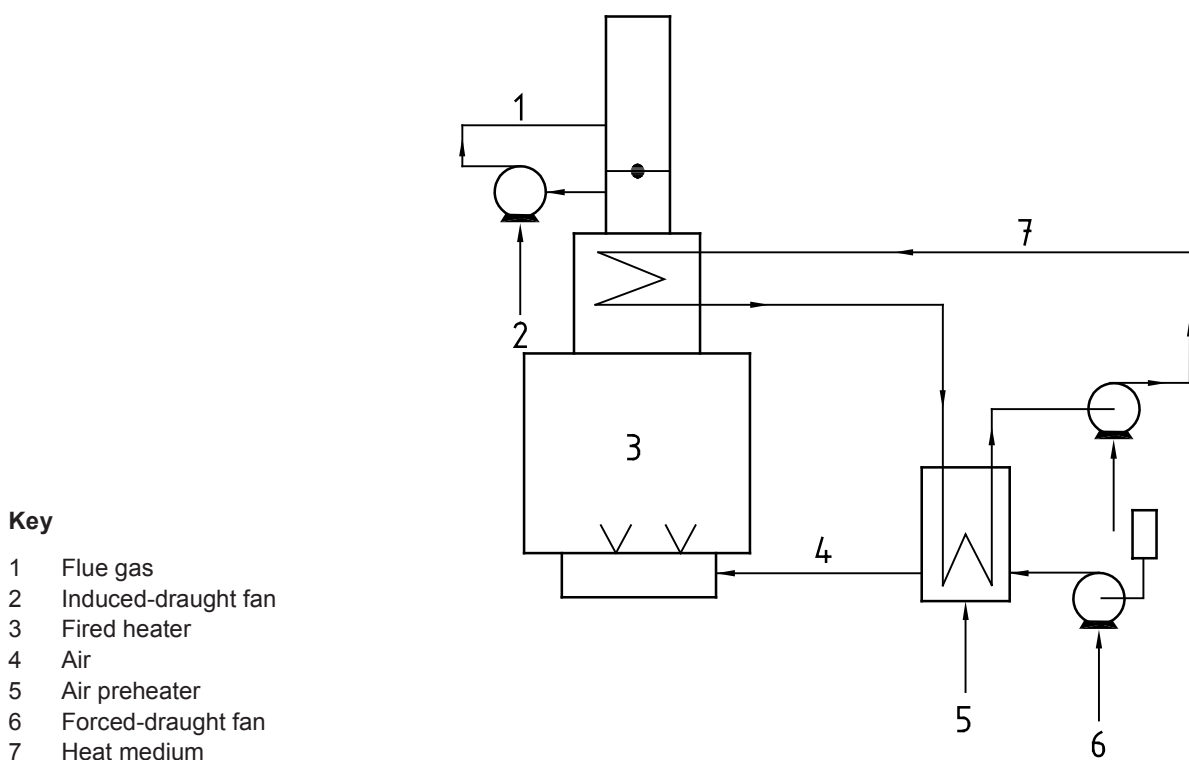


Figure 5 — System using indirect closed system air preheater with mechanical circulation

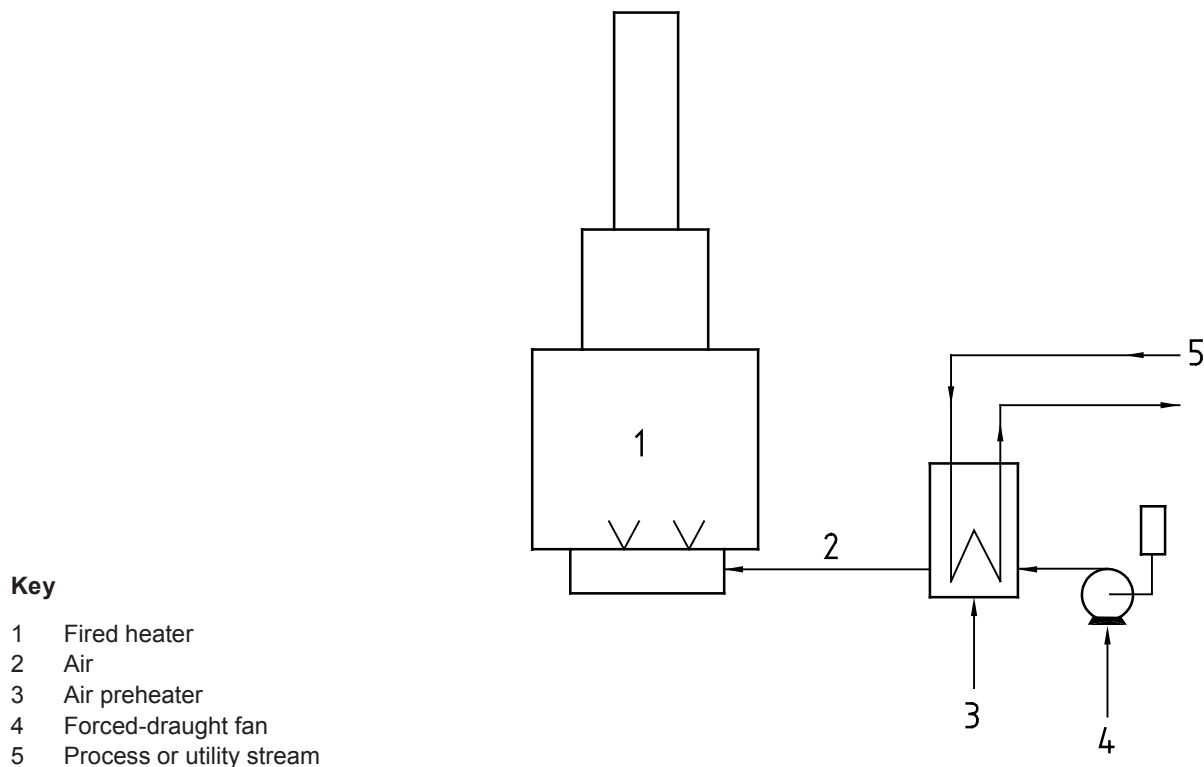


Figure 6 — External heat source for air preheating

5 Proposals

5.1 Purchaser's responsibilities

5.1.1 The purchaser's enquiry shall include data sheets, check list, and other applicable information outlined herein. This information shall include any special requirements or exceptions to this International Standard.

5.1.2 The purchaser is responsible for the correct process specification to enable the vendor to prepare the fired heater design. The purchaser should complete, as a minimum, those items on the data sheet that are designated by an asterisk (*).

5.1.3 The purchase order shall state clearly the vendor's scope of work and extent of supply.

- **5.1.4** The purchaser's enquiry shall specify the number of copies of drawings, data sheets, specifications, data reports, operating manuals, installation instructions, spare parts lists, and other data to be supplied by the vendor, as required by 5.3 and 5.4.

5.2 Vendor's responsibilities

The vendor's proposal shall include:

- a) for each heater, completed ISO data sheets for fired heater and associated equipment (see examples in annex A);
- b) an outline drawing showing firebox dimensions, burner layout and clearances, arrangement of tubes, platforms, ducting, stack, breeching, air pre-heater and fans;
- c) a full definition of the extent of shop assembly (format given in annex C may be used), including the number, size and mass of prefabricated parts and the number of field welds;

- d) a detailed description of any exceptions to the specified requirements;
- e) a completed noise data sheet if the data sheet is supplied by the purchaser;
- f) curves for heaters in vaporizing service, showing pressure, temperature, vaporization and bulk velocity as a function of the tube number;
- g) time schedule for submission of all required drawings, data and documents;
- h) a programme for scheduling the work after receipt of an order. This should include a specified period of time for the purchaser to review and return drawings, procurement of materials, manufacture and the required date of supply;
- i) list of utilities and quantities required.

5.3 Documentation

5.3.1 Drawings for purchaser's review

The vendor shall submit for review the general arrangement drawings, coil drawings and data sheets for each heater. The documents shall include the following information:

- a) heater service, the purchaser's equipment number, the project name and location, the purchase order numbers and the vendor's reference number;
- b) coil terminal sizes, including flange ratings and facings; dimensional locations; direction of process flow; and allowable loads, moments and forces on terminals;
- c) coil and crossover arrangements, tube spacings, tube diameters, tube wall thicknesses, tube lengths, material specifications, including grades for pressure parts only, and all extended surface data;
- d) coil design pressures, hydrostatic test pressures, design fluid and tube wall temperatures, and corrosion allowance;
- e) coil design code or recommended practice and fabrication code or specification;
- f) refractory and insulation types, thicknesses, and service temperature ratings;
- g) types and materials of anchors for refractory and insulation;
- h) location and number of access doors, observation doors, burners, sootblowers, dampers, and instrument and auxiliary connections;
- i) location and dimension of platforms, ladders, and stairways;
- j) overall dimensions, including auxiliary equipment.

5.3.2 Foundation loading diagrams

The vendor shall submit for purchaser's review foundation loading diagrams for each heater. The diagram shall include the following information:

- a) number and location of piers and supports;
- b) baseplate dimensions;
- c) anchor bolt locations, bolt diameters, and projection above foundations;
- d) dead loads, live loads, wind or earthquake loads, reaction to overturning moments, and lateral shear loads.

5.3.3 Documents for purchaser's review

The vendor also shall submit to the purchaser the following documents for review and comment (individual stages of fabrication shall not proceed until the relevant document has been reviewed and commented upon):

- a) structural steel drawings, details of stacks, ducts and dampers, and structural calculations;
- b) burner assembly drawings and burner piping;
- c) tube support details;
- d) thermowell and thermocouple details;
- e) welding, examination and test procedures and welder's test certificates;
- f) installation and test procedures for refractories and insulation;
- g) refractory thickness calculations including temperature gradients through all refractory sections and sources of thermal conductivities;
- h) decoking procedures, if required;
- i) installation, operation and maintenance instructions for the heater and auxiliary equipment, such as air preheaters, fans, drivers, dampers and burners;
- j) performance curves or data sheets for air preheaters, fans, drivers and burners and other auxiliary equipment;
- k) noise data sheets, if data sheets are supplied by the purchaser;
- l) plug header details.

5.3.4 Certified drawings and diagrams

After receipt of the purchaser's comments on the general arrangement drawings and diagrams, the vendor shall furnish certified general arrangement drawings and foundation loading diagrams. The vendor shall furnish design detail drawings, erection drawings, and an erection sequence. Drawings of auxiliary equipment shall also be furnished.

5.4 Final records

Within a specified timescale after completion of construction or shipment, the vendor shall furnish the purchaser with the following documents:

- a) data sheets and drawings representing the as-manufactured equipment. In the event field-changes are made, as-built drawings and data sheets shall not be provided unless specifically requested by the purchaser;
- b) certified material reports, mill test reports or ladle analysis for all pressure parts and alloy-extended surfaces;
- c) installation, operation and maintenance instructions for the heater and auxiliary equipment, such as air preheaters, fans, drivers, dampers and burners;
- d) performance curves or data sheets for air preheaters, fans, drivers and burners and other auxiliary equipment;
- e) bill of materials (major components);
- f) noise data sheets, if data sheets are supplied by the purchaser;
- g) refractory dry-out procedures;

- h) decoking procedures;
- i) test certificates for tube support castings;
- j) all other test documents, including test reports and non-destructive examination reports.

6 Design considerations

6.1 Process design

6.1.1 Heaters shall be designed for uniform heat distribution. Multipass heaters shall be designed for hydraulic symmetry of all passes.

6.1.2 The number of passes for vaporizing fluids shall be minimized. Each pass shall be a single circuit from inlet to outlet.

6.1.3 Average heat flux density in the radiant section is normally based on a single row of tubes spaced at two nominal tube diameters. The first row of shield-section tubes shall be considered as radiant service in determining the average heat flux density if these tubes are exposed to direct flame radiation.

6.1.4 Where the average radiant heat flux density is specified on the basis of two nominal diameters, the vendor may increase the flux rate for other coil arrangements, e.g. for three nominal diameters or double-sided firing, providing the maximum flux, including maldistribution, shall not exceed that based on two nominal diameters.

6.1.5 The maximum allowable inside film temperature for any process service shall not be exceeded in the radiant, shield or convection sections anywhere in the specified coil.

6.2 Combustion design

6.2.1 Margins provided in the combustion system are not intended to permit operation of the heater at greater than the design process duty.

6.2.2 Calculated fuel efficiencies shall be based on the lower heating value of the design fuel and shall include a radiation loss of 1,5 % of the calculated normal fuel heat release. Heaters employing flue gas/air preheat systems shall include a radiation loss of 2,5 % of the fuel heat release based on the lower heating value.

6.2.3 Unless otherwise specified by the purchaser, calculated efficiencies for natural-draught operation shall be based upon 20 % excess air if gas is the primary fuel, and 25 % excess air if oil is the primary fuel. In the case of forced-draught operation, calculated efficiencies shall be based on 15 % excess air for fuel gas and 20 % excess air for fuel oil.

6.2.4 The heater efficiency and tube wall temperature shall be calculated using the specified fouling resistances.

6.2.5 Volumetric heat release of the radiant section shall not exceed 125 kW/m³ (12 000 Btu/h/ft³) for oil-fired heaters and 165 kW/m³ (16 000 Btu/h/ft³) for gas-fired heaters based upon the design heat absorption.

6.2.6 Stack and flue-gas systems shall be designed so that a negative pressure of at least 25 Pa (0,10 in of water column) is maintained in the radiant and convection sections at 120 % of normal heat release with design excess air and maximum ambient temperature.

6.3 Mechanical design

6.3.1 Provisions for thermal expansion shall take into consideration all specified operating conditions, including short-term conditions such as steam-air decoking.

- **6.3.2** If specified by the purchaser, the convection-section tube layout shall include space for future installation of sootblowers, water washing, or steam-lancing doors.

- **6.3.3** If the heater is designed for heavy fuel-oil firing, sootblowers shall be provided for convection-section cleaning. If light fuel oils such as naphtha are to be fired, the purchaser shall specify if sootblowers are to be supplied.

6.3.4 The convection-section design shall incorporate space for the future addition of two rows of tubes, including the end and intermediate tubesheets. Placement of sootblowers and cleaning lanes shall be suitable for the addition of the future tubes. Holes in end tube sheets shall be plugged off to prevent flue gas leakage.

6.3.5 Vertical cylindrical heaters shall be designed with a maximum height-to-diameter (h/w) ratio of 2,75, where the height is that of the radiant section (inside refractory face) and the diameter is that of the tube circle, both measured in the same units.

6.3.6 For single-fired box-type floor-fired heaters with sidewall tubes only, an equivalent h/w factor shall be determined by dividing the height of the wall bank (or the straight tube length for vertical tubes) by the width of the tube bank and applying the following limitations:

Design absorption MW (Btu/h $\times 10^6$)	h/w max.	h/w min.
Up to 3,5 (12)	2,00	1,50
3,5 to 7 (12 to 24)	2,50	1,50
Over 7 (24)	2,75	1,50

6.3.7 Shield sections shall have at least three rows of bare tubes.

6.3.8 Except for the first shield row, convection sections shall be designed with corbels or baffles to minimize the amount of flue gas bypassing the heating surface.

6.3.9 The minimum clearance from grade to burner plenum or register shall be 2 m (6,5 ft) for floor-fired heaters unless otherwise specified by the purchaser.

6.3.10 For vertical-tube vertical-fired heaters, the maximum radiant straight tube length shall be 18,3 m (60 ft). For horizontal heaters fired from both ends, the maximum radiant straight tube length shall be 12,2 m (40 ft).

6.3.11 Radiant tubes shall be installed with minimum spacing from refractory or insulation to tube centreline of 1,5 nominal tube diameters, with a clearance of not less than 100 mm (4 in) from the refractory or insulation. For horizontal radiant tubes, the minimum clearance from floor refractory to tube outside diameter shall be not less than 300 mm (12 in).

6.3.12 The heater arrangement shall allow for replacement of individual tubes or hairpins without disturbing adjacent tubes.

7 Tubes

7.1 General

7.1.1 Tube wall thickness for coils shall be determined in accordance with ISO 13704, in which the practical limit to minimum thickness for new tubes is specified. For materials not included, tube wall thickness shall be determined in accordance with ISO 13704 using stress values mutually agreed upon between purchaser and supplier.

7.1.2 Unless otherwise agreed between the purchaser and supplier, calculations made to determine tube wall thickness for coils shall include considerations for erosion and corrosion allowances for the various coil materials. The following corrosion allowances shall be used as a minimum:

- a) carbon steel through C-1/2Mo: 3 mm (0,118 in);

- b) low alloys through 9Cr-1Mo: 2 mm (0,080 in);
- c) above 9Cr-1Mo through austenitic steels: 1 mm (0,040 in).

7.1.3 Maximum tube-metal temperature shall be determined in accordance with ISO 13704. The tube-metal temperature allowance shall be at least 15 °C (27 °F).

7.1.4 All tubes shall be seamless and should be in single continuous lengths. Electric flash welding shall not be used for intermediate welds. Tubes furnished to an average wall thickness shall be in accordance with suitable tolerances so that the required minimum wall thickness is provided.

7.1.5 Tubes, if projected into header box housings, shall extend at least 150 mm (6 in), in the cold position, beyond the face of the end tube sheet, of which 100 mm (4 in) shall be bare.

7.1.6 Tube size (outside diameter in inches) shall be selected from the following sizes: 2,375; 2,875; 3,50; 4,00; 4,50; 5,563; 6,625; 8,625; or 10,75. Other tube sizes should be used only if warranted by special process considerations.

7.1.7 If the shield and radiant tubes are in the same service, the shield tubes exposed to direct flame radiation shall be of the same material and thickness as the connecting radiant tubes.

7.2 Extended surface

- 7.2.1** The extended surface in convection sections may be studded (where each stud is attached to the tube by arc or resistance welding) or finned (where helically wound fins are high-frequency continuously welded to the tube). The purchaser shall specify or agree the type of extended surface to be provided. In the case of finning, the purchaser shall specify or agree whether the fins shall be solid or segmented.

7.2.2 Metallurgy for the extended surface shall be selected on the basis of maximum calculated tip temperature as listed in Table 1.

7.2.3 Extended surface dimensions shall be limited to those listed in Table 2.

Table 1 — Extended surface materials

Material	Studs		Fins	
	Maximum tip temperature		Maximum tip temperature	
	°C	(°F)	°C	(°F)
Carbon steel	510	(950)	454	(850)
2 1/4 Cr-1Mo, 5Cr-1/2 Mo	593	(1 100)	—	—
11-13 Cr	649	(1 200)	593	(1 100)
18Cr-8Ni stainless steel	815	(1 500)	815	(1 500)
25Cr-20Ni stainless steel	982	(1 800)	982	(1 800)

Table 2 — Extended surface dimensions

Fuel	Studs				Fins					
	Minimum diameter		Maximum height		Minimum normal thickness		Maximum height		Maximum number per unit length	
	mm	(in)	mm	(in)	mm	(in)	mm	(in)	per m	(per in)
Gas	12,5	(1/2)	25	(1)	1,3	(0,05)	25,4	(1)	197	(5)
Oil	12,5	(1/2)	25	(1)	2,5	(0,10)	19,1	(3/4)	118	(3)

7.3 Materials

Tube materials shall conform to ASTM specifications as listed in Table 3, or their equivalent agreed by the purchaser.

Table 3 — Tube materials and ASTM specifications

Material	Tube specification
Carbon steel	A 161, A 192, A 210, Gr A-1
Carbon-1/2Mo	A 161, A 209, Gr T1
1 1/4Cr-1/2Mo	A 213, Gr T11
2 1/4Cr-1Mo	A 213, Gr T22
3Cr-1Mo	A 213, Gr T21
5Cr-1/2Mo	A 213, Gr T5
5Cr-1/2Mo-Si	A 213, Gr TSb
7Cr-1/2Mo	A 213, Gr T7
9Cr-1Mo	A 213, Gr T9
9Cr-1Mo-V	A 213, Gr T91
18Cr-8Ni	A 213, TP 304, TP 304H
16Cr-12Ni-2Mo	A 213, TP 316, TP 316H
18Cr-10Ni-Ti	A 213, TP 321, TP 321H
18Cr-10Ni-Nb ^a	A 213, TP 347, TP 347H
Nickel alloy ^b	B 407
25Cr-20Ni	A 213, TP 310H
25Cr-20Ni	A 608, Gr HK40
^a Formerly called columbium, Cb.	
^b Minimum grain size shall be ASTM #5 or coarser.	

8 Headers

8.1 General

8.1.1 The design stress for headers shall be no higher than that allowed for similar materials as given in ISO 13704 and shall be reduced by casting quality factors if made from castings. Casting quality factors shall be in accordance with ASME B31.3.

8.1.2 Headers shall be of metallurgy equivalent to the tubes.

8.1.3 Headers shall be welded return bends or welded plug headers, depending on the service and operating conditions.

8.1.4 Headers shall have a corrosion allowance. This allowance shall not be less than that used for the tubes.

8.2 Plug headers

8.2.1 Plug headers shall be located in a header box and shall be selected for the same design pressure as the connecting tubes and for a design temperature equal to the maximum fluid operating temperature at that location, plus a minimum of 30 °C (55 °F).

8.2.2 Tubes and plug headers shall be arranged so that there is sufficient space for field maintenance operations such as welding and stress relieving.

8.2.3 If plug headers are specified to permit mechanical cleaning of coked or fouled tubes, they shall consist of the two-hole type. Single-hole, 180° plug headers may be installed only for tube inspection and draining.

8.2.4 If plug headers are specified to be used with horizontal tubes that are 18,3 m (60 ft) or longer, two-hole plug headers shall be used for both ends of the coil assembly. For shorter coils, plug headers shall be provided on one end of the coil with welded return bends on the opposite end.

8.2.5 If plug headers are specified for vertical tube heaters, two-hole plug headers shall be installed on the top of the coil and one-hole Y-fittings at the bottom of the tubes.

8.2.6 Headers and corresponding plugs shall be match-marked by 12 mm (0,5 in) permanent numerals and installed in accordance with a fitting location drawing.

8.2.7 Type 304 stainless steel thermowells, if required for temperature measurement and control, shall be provided in the plugs of the headers.

8.2.8 Tube centre-to-centre dimensions shall be as shown in Table 4.

Table 4 — Tube centre-to-centre dimensions

Tube outside diameter mm (in)	Header centre-to-centre dimension	
	mm	(in)
60,3 (2,375)	101,6	4,00 ^{a, b}
73,0 (2,875)	127,0	5,00 ^{a, b}
88,9 (3,50)	152,4	6,00 ^a
101,6 (4,00)	177,8	7,00 ^a
114,3 (4,50)	203,2	8,00 ^a
127,0 (5,00)	228,6	9,00
141,3 (5,563)	254,0	10,00 ^a
152,4 (6,00)	279,4	11,00
168,3 (6,625)	304,8	12,00 ^a
193,7 (7,625)	355,6	14,00
219,1 (8,625)	406,4	16,00 ^a
273,1 (10,75)	508,0	20,00 ^a
NOTE Centre-to-centre dimensions are applicable only to manufacturer's standard header pressure ratings for 5 850 kPa (850 psig) nominal fittings.		
^a This centre-to-centre dimension equals two times the corresponding nominal size and is based on the centre-to-centre dimension for short-radius welded return bends.		
^b This centre-to-centre dimension is applicable only to welded plug headers.		

8.2.9 Plugs and screws shall be assembled in the fittings with an approved compound on the seats and screws to prevent galling.

8.3 Return bends

8.3.1 Return bends should be used for the following conditions:

- a) in clean service, where coking or fouling of tubes is not anticipated;
- b) where leakage is a hazard;
- c) where steam-air decoking facilities are provided for decoking of furnace tubes.

8.3.2 Return bends inside the firebox shall be selected for the same design pressure and temperature as the connecting tubes. Return bends inside a header box shall be selected for the same design pressure as the connecting tubes and for a design temperature equal to the maximum fluid operating temperature at that location plus a minimum of 30 °C (55 °F). Return bends shall be at least the same thickness as the connecting tubes.

8.3.3 Regardless of the location of the welded return bends, the heater design shall incorporate means to permit convenient removal and replacement of tubes and return bends.

8.3.4 Longitudinally welded fittings shall not be used.

8.4 Materials

8.4.1 Plug header and return bend material shall conform to the ASTM specifications listed in Table 5 or to other specifications if agreed by the purchaser.

8.4.2 Cast fittings shall have the material identification permanently marked on the fitting with raised letters or by using low-stress stamps.

Table 5 — Plug header and return bend materials (ASTM specifications)

Material	Forged	Wrought	Cast
Carbon steel	A 105	A 234, WPB	A 216, WCB
	A 181, class 60 or 70		
C-1/2Mo	A 182, F1	A 234, WP1	A 217, WC1
1 1/4Cr-1/2Mo	A 182, F11	A 234, WP11	A 217, WC6
2 1/4Cr-1Mo	A 182, F22	A 234, WP22	A 217, WC9
3Cr-1Mo	A 182, F21	—	—
5Cr-1/2Mo	A 182, F5	A 234, WP5	A 217, C5
9Cr-1Mo	A 182, F9	A 234, WP9	A 217, C12
18Cr-8Ni-Type 304	A 182, F304	A 403, WP304	A 351, CF8
18Cr-8Ni-Type 304H	A 182, F304H	A 403, WP304H	A 351, CF8
18Cr-10Ni-Ti- Type 321	A 182, F321	A 403, WP321	A 351, CF8C
18Cr-10Ni-Ti-Type 321H	A 182, F321H	A 403, WP321H	
18Cr-10Ni-Nb Type 347	A 182, F347	A 403, WP347	A 351, CF8C
18Cr-10Ni-Nb Type 347H	A 182, F347H	A 403, WP347H	
16Cr-12Ni-2Mo Type 316	A 182, F316	A 403, WP316	A 351, CF8M
16Cr-12Ni-2Mo Type 316H	A 182, F316H	A 403, WP316H	
Nickel alloy ^a	B 564	B 366	A 351, CT-15C
25Cr-20Ni	A 182, F-310	A 403, F-310	A 351, CK-20 A 351, HK40

^a Minimum grain size shall be ASTM #5 or coarser.

9 Piping, terminals and manifolds

9.1 General

9.1.1 The minimum corrosion allowance shall be in accordance with 7.1.2.

9.1.2 All flanges shall be welding-neck flanges.

9.1.3 Piping, terminals and manifolds external to the heater enclosure shall be in accordance with ASME B31.3.

- 9.1.4 The purchaser shall specify if inspection openings are required; in which case, if agreed by the purchaser, terminal flanges may be used provided that pipe sections are readily removable for inspection access.

9.1.5 Threaded connections shall not be used.

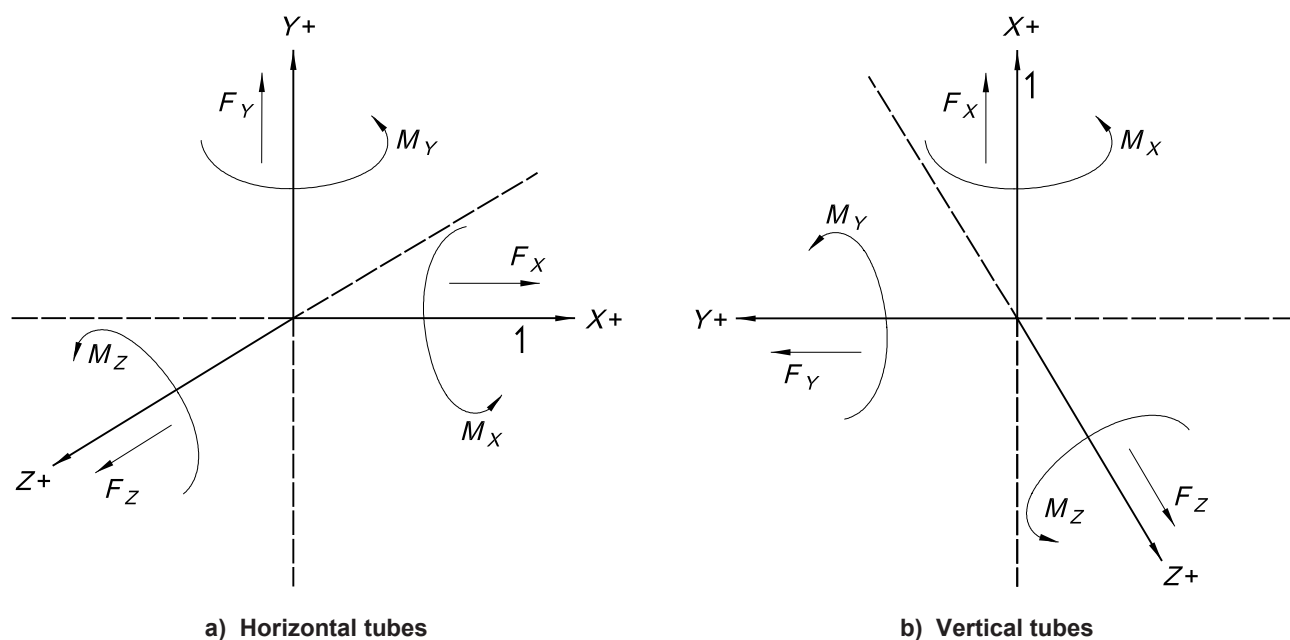
- 9.1.6 The purchaser shall specify if low-point drains and high-point vents are required; in which case they shall be accessible from outside the heater casing.

9.1.7 Manifolds and external piping shall be located so as not to block access for the removal of single tubes or hairpins.

9.1.8 Manifolds inside a header box shall be selected for the same design pressure as the connecting tubes and for a design temperature equal to the maximum fluid operating temperature at that location plus a minimum of 30 °C (55 °F).

9.2 Allowable movement and loads

Heater terminals shall be designed to accept the moments (M) and forces (F) shown in Figure 7 and Table 6, or the movements listed in Table 7.



Key

1 Tube centreline

Figure 7 — Diagram of forces

Table 6 — Allowable forces and moments

Pipe size DN (NPS)	F_x		F_y		F_z		M_x		M_y		M_z	
	N	(lb)	N	(lb)	N	(lb)	N·m	(ft·lb)	N·m	(ft·lb)	N·m	(ft·lb)
50 (2)	445	(100)	890	(200)	890	(200)	475	(350)	339	(250)	339	(250)
75 (3)	667	(150)	1 334	(300)	1 334	(300)	610	(450)	475	(350)	475	(350)
100 (4)	890	(200)	1 779	(400)	1 779	(400)	813	(600)	610	(450)	610	(450)
125 (5)	1 001	(225)	2 002	(450)	2 002	(450)	895	(660)	678	(500)	678	(500)
150 (6)	1 112	(250)	2 224	(500)	2 224	(500)	990	(730)	746	(550)	746	(550)
200 (8)	1 334	(300)	2 669	(600)	2 669	(600)	1 166	(860)	881	(650)	881	(650)
250 (10)	1 557	(350)	2 891	(650)	2 891	(650)	1 261	(930)	949	(700)	949	(700)
300 (12)	1 779	(400)	3 114	(700)	3 114	(700)	1 356	(1 000)	1 017	(750)	1 017	(750)

Table 7 — Allowable movements

Dimensions in millimetres (inches)

	Horizontal tubes						Vertical tubes					
	Δx		Δy		Δz		Δx		Δy		Δz	
Radiant terminals	0	(0)	25	(1)	25	(1)	0	(0)	25	(1)	25	(1)
Convection terminals	0	(0)	13	(0,5)	13	(0,5)	—	—	—	—	—	—
NOTE The above movements are allowable in both directions ($\pm$)												

9.3 Materials

External crossover piping shall be of the same metallurgy as the preceding heater tube; internal crossover piping shall be of the same metallurgy as the radiant tubes.

10 Tube supports

10.1 General

10.1.1 The design temperature for tube supports and guides exposed to flue gas shall be based on design operation of the furnace as follows:

- for the radiant and shock sections and outside the refractory, the flue-gas temperature to which the supports are exposed plus 100 °C (180 °F). The minimum design temperature shall be 870 °C (1 600 °F);
- for the convection section, the temperature of the flue gas in contact with the support plus 55 °C (100 °F);
- the maximum flue-gas temperature gradient across a single convection intermediate tube support shall be 250 °C (450 °F);
- where the radiant tube support castings are shielded behind a row of tubes, the bridgewall temperature may be used.

No credit shall be taken for the shielding effect of refractory coatings on intermediate supports or guides.

10.1.2 Guides, horizontal radiant-section intermediate tube supports and top supports for vertical radiant tubes shall be designed to permit their replacement without tube removal and with minimum refractory repair.

10.1.3 The unsupported length of horizontal tubes shall not exceed 35 times the outside diameter or 6 m (20 ft), whichever is less.

10.1.4 The minimum corrosion allowance of each side for all exposed surfaces of each tube support and guide contacting flue gases shall be 1,3 mm (0,05 in) for austenitic materials and 2,5 mm (0,10 in) for ferritic materials.

10.1.5 The following shall apply to end tube sheets for tubes with external headers.

- Tube sheets shall be structural plate. If the tube sheet design temperature exceeds 425 °C (800 °F), alloy materials shall be used.
- Minimum thickness of tube sheets shall be 12 mm (0,5 in).
- Tube sheets shall be insulated on the flue-gas side with a castable having a minimum thickness of 75 mm (3 in) for the convection section and 125 mm (5 in) for the radiant section. (Anchors shall be made from austenitic stainless steel or nickel alloy as listed in Table 9.)
- Sleeves with an inside diameter at least 12 mm (0,5 in) greater than the tube or the extended surface outside diameter shall be welded to the tube sheet at each tube hole, to prevent the refractory from being damaged by the tubes. The sleeve material shall be austenitic stainless steel.

10.1.6 The following shall apply to the supporting of extended surface tubes.

- Intermediate supports shall be designed to prevent mechanical damage to the extended surface and shall permit easy removal and insertion of the tubes without binding.
- For studded tubes, a minimum of three rows of studs shall rest on each support.
- For finned tubes, at least five fins shall rest on each support.

10.2 Loads and allowable stress

10.2.1 Tube-support loads shall be determined as follows.

- Loads shall be determined in accordance with acceptable procedures for supporting continuous beams on multiple supports (e.g. AISC). Friction loads shall be based on a friction coefficient of not less than 0,30.
- Friction loads shall be based on all tubes expanding and contracting in the same direction. Loads shall not be considered to be cancelled or reduced due to movement of tubes in opposite directions.

10.2.2 Tube-support maximum allowable stresses at design temperature shall not exceed the following:

a) dead-load stress:

- 1) one-third of the ultimate tensile strength;
- 2) two-thirds of the yield strength (0,2 % offset);
- 3) 50 % of the average stress required to produce 1 % creep in 10 000 h.;
- 4) 50 % of the average stress required to produce rupture in 10 000 h.

b) dead-load plus frictional stress:

- 1) one-third of the ultimate tensile strength;
- 2) two-thirds of the yield strength (0,2 % offset);

- 3) the average stress required to produce 1 % creep in 10 000 h;
- 4) the average stress required to produce rupture in 10 000 h.

10.2.3 For castings, the allowable stress value shall be multiplied by 0,8.

10.2.4 Stress data shall be as presented in annex D.

10.3 Materials

10.3.1 Tube support materials shall be selected for maximum design temperatures as shown in Table 8. Other materials and alternative specifications shall be subject to the approval of the purchaser.

- **10.3.2** If the tube support design temperature exceeds 650 °C (1 200 °F) and the fuel contains more than 100 mg/kg total vanadium and sodium, the supports shall exhibit one of the following design details, as specified or agreed by the purchaser:

- a) constructed of stabilized, 50Cr-50Ni metallurgy, without any coating;
- b) for radiant or accessible supports only, covered with 50 mm (2 in) of castable refractory having a minimum density of 2 080 kg/m³ (130 lb/ft³).

Table 8 — Maximum design temperatures for tube support materials

Material	Casting ASTM specification	Plate ASTM specification	Maximum design temperature	
			°C	(°F)
Carbon steel	A 216 Gr WCB	A 283 Gr C	425	(800)
2 1/4Cr-1Mo	A 217 Gr WC 9	A 387 Gr 22, Class 1	650	(1 200)
5Cr-1/2Mo	A 217 Gr C5	A 387 Gr 5, Class 1	650	(1 200)
19Cr-9Ni	A 297 Gr HF	A 240, Type 304H	815	(1 500)
25Cr-12Ni		A 240, Type 309H	870	(1 600)
25Cr-12Ni	A 447 Type II		980	(1 800)
25Cr-20Ni		A 240, Type 310H	870	(1 600)
25Cr-20Ni	A 351 Gr HK40		1 090	(2 000)
50Cr-50Ni-Nb	A 560 Gr 50Cr-50Ni		980	(1 800)
For exposed radiant and shield-section tube supports, the material shall be 25Cr-12Ni or higher alloy				

11 Refractories and insulation

11.1 General

11.1.1 The temperature of the outside casing of the radiant and convection sections and hot ductwork shall not exceed 80 °C (175 °F) at an ambient temperature of 27 °C (80 °F) in still air. Radiant floors shall not exceed 90 °C (195 °F).

11.1.2 Walls, arches and floors shall be designed to allow for proper expansion of all parts. Where multilayer or multicomponent linings are used, joints shall not be continuous through the lining.

11.1.3 Any layer of refractory shall be suitable for a service temperature at least 165 °C (300 °F) above its calculated hot-face temperature. Minimum service temperature for refractories shall be 980 °C (1 800 °F) in the radiant and shield sections.

11.1.4 The floor hot surface shall be a 63 mm (2,5 in) thick layer of high-duty fireclay brick or a 75 mm (3 in) thick layer of castable of 1 370 °C (2 500 °F) service temperature and minimum cold crush strength of 3 450 kN/m² (500 psi) after drying at 110 °C (230 °F).

11.1.5 Burner blocks shall be suitable for an operating temperature of at least 1 650 °C (3 000 °F).

11.1.6 Target walls with flame impingement on both sides shall be constructed of high-duty firebrick of at least 1 540 °C (2 800 °F) rating. Bricks shall be laid dry or with mortared joints. Expansion joints shall be packed with ceramic fibre strips having a service temperature rating not less than 1 540 °C (2 800 °F).

11.1.7 Target walls with flame impingement on one side shall be of brick or of plastic refractory of equivalent maximum service temperature. Either may be backed by a castable or ceramic fibre board.

11.1.8 Access doors shall be protected from direct radiation by a refractory system of at least the same thermal rating and resistance as the adjacent wall lining.

11.1.9 Refractory anchors are not mandatory for floor castable unless required for shipping considerations.

11.1.10 Maximum temperatures for anchor tips are listed in Table 9.

Table 9 — Maximum temperatures for anchor tips

Anchor material	Maximum anchor temperature	
	°C	(°F)
Carbon steel	455	850
TP 304 stainless steel	760	1 400
TP 316 stainless steel	760	1 400
TP 309 stainless steel	815	1 500
TP 310 stainless steel	927	1 800
TP 330 stainless steel	1 038	1 900
Alloy 601 (UNS N06601)	1 093	2 000
Ceramic studs and washers	> 1 093	> 2 000

11.2 Brick and tile construction

11.2.1 Brick construction may be used for gravity walls, floors, or as hot-face layers.

11.2.2 Radiant chamber walls of gravity construction shall not exceed 7,3 m (24 ft) in height and shall be at least high-duty fireclay brick. The base width shall be a minimum of 8 % of wall height. The height-to-width ratio of each wall section shall not exceed 5 to 1. The walls shall be self-supporting and the base shall rest on the steel wall, not on another refractory.

11.2.3 Gravity walls shall be of mortared construction. The mortar shall be non-slagging, air-setting, chemically compatible with adjacent refractory, including at the rated temperature of the brick.

11.2.4 Vertical expansion joints shall be provided at gravity wall ends and required intermediate locations. All expansion joints shall be kept open and free to move. If the joint is formed with lapped brick, no mortar shall be used, that is, it shall be a dry joint.

11.2.5 Floor brick shall not be mortared. A 13 mm (0,5 in) gap for expansion shall be provided at 1,8 m (6 ft) intervals. This gap may be packed with fibrous refractory material in strip, not loose bulk, form.

11.2.6 Minimum service temperature for a hot-face brick layer shall be 1 430 °C (2 600 °F) on walls with expected flame impingement and 1 260 °C (2 300 °F) for other exposed-wall applications. Minimum service temperature for shielded walls shall be 1 095 °C (2 000 °F).

11.2.7 All brick linings on vertical flat casing shall be tied back to and supported by the structural steel framing members. All tie members shall be austenitic alloy material, except that pipe supports located in the backup layer may be carbon steel. At least 15 % of the bricks shall be tied back. Brick lining on cylindrical casing need not be tied back if the radius of curvature of the casing keys the bricks.

11.2.8 Brick linings shall be supported by metal support shelves (lintels) attached to the casing on vertical centres not to exceed 1,8 m (6 ft). Support shelves shall be slotted to provide for differential thermal expansion. Shelf material is defined by the calculated service temperature; carbon steel is satisfactory up to 370 °C (700 °F).

11.2.9 Expansion joints shall be provided in both vertical and horizontal directions of the walls, at wall edges and about burner tiles, doors and sleeved penetrations.

11.3 Castable construction

11.3.1 Hydraulic-setting castables are suitable as lining for all parts of fired heaters. If a castable construction of 1:2:4 volumetric mix of Lumnite-haydite-vermiculite is used, the maximum service temperature shall not exceed 1 040 °C (1 900 °F). If used as a hot face, it shall only be used in clean fuel applications. This castable shall be limited to 200 mm (8 in) maximum thickness on arches and walls.

11.3.2 For dual layer castable construction, the hot face layer shall be a minimum of 75 mm (3 in) thick. The anchoring systems shall provide independent support for each layer.

11.3.3 Anchoring penetration shall be not less than 70 % of the individual layer being anchored for castable thickness greater than 50 mm (2 in). The anchor shall not be closer than 12 mm (0,5 in) to the hot face.

11.3.4 The anchoring spacing shall be a maximum of three times the total lining thickness, but shall not exceed 300 mm (12 in) on a square pattern for walls and 225 mm (9 in) on a square pattern for arches. The anchor orientation shall be varied to avoid creating continuous shear planes.

11.3.5 Anchors for total castable thickness up to 150 mm (6 in) shall be at least 5 mm (3/16 in) in diameter. For greater castable thickness, the anchors shall be at least 6,3 mm (1/4 in) in diameter.

11.3.6 Castable linings in header boxes, breechings and lined flue-gas ducts and stacks shall not be less than 50 mm (2 in) thick.

- **11.3.7** In castable linings up to 50 mm (2 in) thick, the purchaser shall specify or agree whether bare carbon steel fencing or wire mesh shall be used for anchoring the lining.

11.3.8 Expansion joints shall be provided around burner blocks, brick and prefired shapes.

11.3.9 Metallic fibre may be added for reinforcement only in castables of density 970 kg/m³ (55 lb/ft³) or higher. Metallic fibres shall be limited to no more than 3 % mass fraction of the dry mixture.

11.3.10 Castables of low iron content (less than 1 % iron) or heavy-weight castable shall be used on exposed hot-face walls if the total heavy metals content, including sodium, within the fuel exceeds 250 mg/kg (250 ppm). Heavy-weight castables shall have a minimum density of 1 800 kg/m³ (110 lb/ft³) with an Al₂O₃ content of not less than 40 %. In aggregate, the Al₂O₃ content shall be not less than 40 % and the SiO₂ content shall not exceed 35 %.

11.4 Ceramic fibre construction

11.4.1 Ceramic fibre in layered or modular construction may be used in all heater areas except stacks, ducts and floors.

11.4.2 The hot face of layered ceramic-fibre blanket installations shall be a minimum of 25 mm (1 in) thick, 128 kg/m³ (8 lb/ft³) density, needled material. Ceramic fibre board, if applied as a hot-face layer, shall not be less than 38 mm (1,5 in) thick nor less than 240 kg/m³ (14 lb/ft³) density. Backup layer(s) of ceramic fibre blanket shall be needled material with a minimum density of 96 kg/m³ (6 lb/ft³). Ceramic fibre board size, if used as hot-face layer, shall be limited to maximum dimensions of 600 mm × 600 mm (24 in × 24 in) if temperatures of the flue gases are below 1 100 °C (2 000 °F) and 450 mm × 450 mm (18 in × 18 in) if temperatures of the flue gases exceed 1 100 °C (2 000 °F).

11.4.3 Any layer of ceramic fibre shall be suitable for a service temperature at least 280 °C (500 °F) above its calculated hot-face temperature.

11.4.4 The hot-face layer of a ceramic fibre blanket system shall be anchored at a maximum distance of 75 mm (3 in) from all edges.

11.4.5 The anchor spacing for arches shall not exceed the following rectangular pattern: 150 mm × 225 mm (6 in × 9 in) for 300 mm (12 in) wide blankets; 225 mm × 225 mm (9 in × 9 in) for 600 mm (24 in) wide blankets; 225 mm × 250 mm (9 in × 10 in) for 900 mm (36 in) wide blankets; and 225 mm × 270 mm (9 in × 10,5 in) for 1 200 mm (48 in) wide blankets.

11.4.6 The anchor spacing for walls shall not exceed the following rectangular pattern: 150 mm × 300 mm (6 in × 12 in) for 300 mm (12 in) wide blankets; 225 mm × 300 mm (9 in × 12 in) for 600 mm (24 in) wide blankets; and 270 mm × 300 mm (10,5 in × 12 in) for 1 200 mm (48 in) wide blankets.

11.4.7 Metallic anchor parts that are not shielded by tubes shall be completely wrapped with ceramic fibre patches or be protected by ceramic retainer cups filled with mouldable ceramic fibre.

11.4.8 Ceramic fibre blanket shall not be used as the hot-face layer if flue gas velocities are in excess of 12 m/s (40 ft/s). Wet blanket, ceramic fibre board, or ceramic fibre modules shall be used on hot-face layers with velocities greater than 12 m/s (40 ft/s) but less than 24 m/s (80 ft/s). Hot-face refractory with velocities greater than 24 m/s (80 ft/s) shall have castable or external lining.

11.4.9 Ceramic fibre blanket shall be installed with its longest dimension in the direction of gas flow. The hot-face layer of blanket shall be constructed with all joints overlapped. Overlaps shall be in the direction of gas flow. Hot-face layers of ceramic fibre board shall be constructed with tight butt joints.

11.4.10 Ceramic fibre blanket used in backup layers shall be installed with butt joints with at least 25 mm (1 in) compression on the joints. All joints in successive layers of blanket shall be staggered.

11.4.11 Ceramic fibre blanket modules shall be installed in soldier course (with batten strips) patterns. Parquet pattern may be used only on arches.

11.4.12 Module systems shall be installed so that joints at each edge are compressed to avoid gaps due to shrinkage.

11.4.13 Modules applied in arches shall be designed so that anchorage is provided over at least 80 % of the module width.

11.4.14 Anchors shall be attached to the casing before modules are installed.

11.4.15 Anchor assembly shall be located in the module at a maximum distance of 50 mm (2 in) from the module cold face.

11.4.16 Module internal hardware shall be austenitic stainless steel or nickel alloy (see Table 9).

- **11.4.17** If ceramic fibre construction is used with fuels having a sulfur content exceeding 10 mg/kg, the casing shall have an internal protective coating, specified or agreed by the purchaser, to prevent corrosion. The protective coating shall be rated for 150 °C (300 °F) service temperature.

11.4.18 A vapour barrier of austenitic stainless steel foil shall be provided if the fuel sulfur content exceeds 500 mg/kg. The vapour barrier shall be located so that the exposure temperature is at least 55 °C (100 °F) above the calculated acid dew point for all operating cases. Vapour-barrier edges shall be overlapped at least 175 mm (7 in); edges and punctures shall be sealed.

11.4.19 Ceramic fibre systems shall not be applied for services where the total heavy metals content in the fuel exceeds 100 mg/kg.

11.4.20 Ceramic fibre shall not be used in convection sections where sootblowers, steam lances or waterwash facilities are initially provided.

11.4.21 Anchors shall be installed before applying protective coating to the casing. The coating shall cover the anchors so that uncoated parts are above the acid dew-point temperature.

11.5 Multicomponent lining construction

11.5.1 Hot-face castable layers shall have a minimum thickness of 75 mm (3 in).

11.5.2 The anchoring system shall provide retention and support for each component layer.

11.5.3 Anchor types and installation for individual lining components shall meet the applicable requirements of 11.2, 11.3, and 11.4.

11.5.4 The material used in any layer shall be suitable for service temperature in accordance with 11.1.3 and 11.4.3.

11.5.5 Brick may be used for hot-face service or as a backup layer if the hot-face layer is brick.

11.5.6 Block insulation shall be made of ceramic fibre or calcium silicate with a minimum service temperature rating of 900 °C (1 650 °F). Block insulation shall only be used as a backup material, but shall not be used if the fuel sulfur content exceeds 1 % mass fraction in liquid fuel or 100 mg/kg hydrogen sulfide in gas fuel. Block insulation used as backup material in floor constructions shall be approved by the purchaser.

- **11.5.7** If insulating block or ceramic fibre is used as backup insulation, the casing shall have a protective coating, specified or agreed by the purchaser, if the fuel sulfur content exceeds 10 mg/kg. The protective coating shall be rated for 150 °C (300 °F) service temperature.

11.5.8 If used as backup for castable, block insulation or ceramic fibre blanket shall be sealed to prevent water migration from the castable.

11.5.9 The minimum density of insulating block and ceramic fibre blanket used as backup materials shall be 130 kg/m³ (8 lb/ft³).

11.6 Materials

11.6.1 Materials shall conform to the following ASTM specifications or equivalent:

- a) fireclay brick, ASTM C 27;
- b) insulating firebrick, ASTM C 155;
- c) castable refractory, ASTM C 401, Class N, O, P, Q, or R;
- d) vermiculite sieve analysis, ASTM C 332, Group 1 density;
- e) insulating block (mineral slag wool, neutral pH), ASTM C 612 CL5;

f) haydite, ASTM C 332 Group II:

- 1) Poured application: Fine aggregate No. 4.
- 2) Gunned application: combined fine and coarse 10 mm (3/8 in) to Fine Aggregate No. 0.

11.6.2 The following materials shall have a composition as follows:

- a) lumnite or calcium aluminate cement: the mass fraction of Al_2O_3 shall be at least 35 %;
- b) ceramic fibre: the mass fraction of Al_2O_3 shall be at least 45 % and the remainder shall be primarily SiO_2 or ZrO_2 .

12 Structures and appurtenances

12.1 General

- **12.1.1** The purchaser shall specify or agree the structural design code. Structures shall comply with the structural design code.

12.1.2 Minimum design loads for wind and earthquake shall conform to the structural design code.

12.1.3 Platform live loads shall be in accordance with the structural design code.

12.1.4 Structures and appurtenances shall be designed for all applicable load conditions expected during shipment, erection and operation. Cold weather conditions shall be considered, particularly when the furnace is not in operation. These load conditions shall include, but are not limited to, dead load, wind load, earthquake load, live load and thermal load.

12.1.5 Design metal temperature of structures and appurtenances shall be the calculated metal temperature plus 55 °C (100 °F), based on the maximum flue gas temperature expected for all operating modes with an ambient temperature of 27 °C (80 °F) in still air.

12.1.6 The effect of elevated design temperature on yield strength and modulus of elasticity shall be taken into account (see Table 10).

12.1.7 The material of the structures and appurtenances shall be adequate for all load conditions at the lowest specified ambient temperature when the furnace is not in operation.

12.2 Structures

12.2.1 All loads from the tubes and headers shall be supported by the structural steel and shall not be transmitted into the refractory.

12.2.2 Structural steel shall be designed to permit lateral and vertical expansion of all heater parts.

12.2.3 Heater casing shall be plate of a minimum thickness of 5 mm (3/16 in), which shall be reinforced against warping. Casing, if calculated to resist buckling stresses, shall have a minimum thickness of 6 mm (1/4 in). Floor and radiant roof plates shall have a minimum thickness of 6 mm (1/4 in).

12.2.4 Heater casing plate shall be seal-welded externally to prevent air and water infiltration.

- **12.2.5** The heater structure shall be capable of supporting ladders, stairs and platforms in locations where installed or where specified by the purchaser for future use.

12.2.6 Flat roof design shall allow for runoff of rainwater. This can be accomplished by arrangement of structural members and drain openings, by sloping the roof or with a secondary roof for weather protection. If pitched roofs are provided for weather protection, eaves and gables shall prevent the entry of windblown rain.

- **12.2.7** If fireproofing is specified by the purchaser, the main structural columns of the heater from the baseplate to the floor level plus the main floor beams shall be designed for the addition of 50 mm (2 in) of fireproofing.

12.2.8 Heaters with horizontal tubes that have return bends inside the firebox shall have removable end panels or panels in the sidewalls, to provide access to the return-bend welds.

12.2.9 Duct structural systems shall support ductwork independent of expansion joints during operation, when idle or with duct sections removed.

12.3 Header boxes, doors and ports

12.3.1 Header boxes

12.3.1.1 Each header box shall allow for the total tube expansion. A minimum clearance of 75 mm (3 in) shall be provided between the header box door refractory and the header in the hot position.

- **12.3.1.2** Header boxes enclosing plug headers shall have hinged doors or bolted end panels as specified by the purchaser.

12.3.1.3 Header boxes, including doors, shall be of 5 mm (3/16 in) minimum steel plate reinforced against warping. Header boxes shall be removable.

- **12.3.1.4** If specified by the purchaser, to minimize flue gas bypassing, horizontal partitions shall be provided in convection-section header boxes at a spacing no greater than 1,5 m (5 ft).

12.3.2 Doors and ports

12.3.2.1 Two access doors having a minimum clear opening of 600 mm × 600 mm (24 in × 24 in) shall be provided for each radiant chamber of a box or cabin heater.

12.3.2.2 One access door having a minimum clear opening of 450 mm × 450 mm (18 in × 18 in) shall be provided in the floor for vertical cylindrical heaters. A bolted and gasketed access door shall also be provided in any air plenum below the floor accessway. Where space is not available, access via a burner port is acceptable.

12.3.2.3 One access door having a minimum clear opening of 600 mm × 600 mm (24 in × 24 in), or 600 mm (24 in) in diameter, shall be provided in the stack or breeching for access to the damper and convection sections.

12.3.2.4 One tube-removal door having a minimum clear opening of 450 mm × 600 mm (18 in × 24 in) shall be provided in the arch of each radiant chamber of vertical tube heaters.

12.3.2.5 Observation doors and ports shall be provided for viewing all radiant tubes and all burner flames for proper operation and light-off.

12.3.2.6 Access doors shall be provided to ducts, plenums and at all duct connections to air preheaters and control dampers.

12.4 Ladders, platforms and stairways

12.4.1 Platforms shall be provided as follows:

- a) at burner and burner controls that are not accessible from grade;
- b) at both ends of the convection section for maintenance purposes;

- c) at damper and sootblower locations for maintenance and operation purposes;
- d) at all observation ports and firebox access doors not accessible from grade;
- e) at auxiliary equipment, such as steam drums, fans, drivers, and air preheaters as required for operating and maintenance purposes;
- f) at all areas necessary to meet the requirements of 15.5.

12.4.2 Vertical cylindrical heaters with shell diameters greater than 3 m (10 ft) shall have a full circular platform at the floor level. Individual ladders and platforms to each observation door may be used if shell diameters are 3 m (10 feet) or less.

12.4.3 Platforms shall have a minimum clear width as follows:

- a) operating platforms, 900 mm (3 ft);
- b) maintenance platforms, 900 mm (3 ft);
- c) walkways, 750 mm (2,5 ft).

- **12.4.4** Platform decking shall have a minimum thickness of 6 mm (1/4 in) checkered plate or 25 mm × 5 mm (1 in × 3/16 in) open grating, as specified by the purchaser. Stair treads shall be open grating with checkered plate nosing.

12.4.5 Dual access shall be provided to each operating platform, except if the individual platform length is less than 6 m (20 ft).

12.4.6 An intermediate landing shall be provided if the vertical rise exceeds 9 m (30 ft) for ladders and 4,5 m (15 ft) for stairways.

12.4.7 Ladders shall be caged from a point 2,3 m (7,5 ft) above grade. A safety gate shall be provided for all ladders serving platforms or landings.

12.4.8 Stairs shall have a minimum width of 750 mm (2,5 ft), a minimum tread width of 240 mm (9,5 in), and a maximum riser of 200 mm (8 in). The slope of the stairway shall not exceed a 9 (vertical) to 12 (horizontal) ratio.

12.4.9 Headroom over platforms, walkways and stairways shall be a minimum of 2,1 m (7 ft).

12.4.10 Handrails shall be provided on all platforms, walkways and stairways.

12.4.11 Handrails, ladders and platforms shall be arranged so as not to interfere with tube handling. Where interference exists, removable sections shall be provided.

12.5 Materials

- **12.5.1** Materials for service at design ambient temperatures below – 30 °C (– 20 °F) shall be as specified by the purchaser. For ambient temperatures below – 20 °C (– 5 °F), special low temperature steels shall be considered.

12.5.2 The mechanical properties and the chemical composition of structural, alloy or stainless steels shall comply with ISO Standard requirements or their equivalent.

12.5.3 For metal temperatures lower than 425 °C (800 °F), stacks, ducts and breeching shall be constructed from one of the following structural grades of steel: EN 10025 (grades Fe360, Fe430, Fe510), ASTM (A 36, A 242, A 572), or their equivalent.

12.5.4 If metal temperatures exceed 425 °C (800 °F), stainless or alloy steels shall be used.

12.5.5 The mechanical properties of the steels at temperatures between 0 °C (32 °F) and 425 °C (800 °F) shall be determined according to the values given in Table 10.

12.5.6 If the minimum service temperature is –18 °C (0 °F) or higher, bolting material shall be in accordance with ASTM A 307, A 325, A 193-B7 or equivalent. Below –18 °C (0 °F), A 193-B7 bolts with A 194-2H nuts, A 320-L7 bolting or equivalent shall be used. No welding is permitted on A 320-L7 or A 193-B7 materials.

Table 10 — Minimum yield strength F_y and modulus of elasticity E for structural steel

T °C (°F)	EN 10025 Fe 360		EN 10025 Fe 430		EN 10025 Fe 510		ASTM A 36		ASTM A 242		ASTM A 572	
	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)	F_y MN/m ² (psi × 10 ³)	E GN/m ² (psi × 10 ⁶)
20 (70)	235 (34,1)	210 (30,5)	275 (39,9)	210 (30,5)	355 (51,5)	210 (30,5)	248 (36,0)	200 (29,0)	290 (42,1)	192 (27,8)	344 (50,0)	207 (30,0)
200 (390)	207 (30,0)	202 (29,3)	242 (35,1)	202 (29,3)	312 (45,3)	202 (29,3)	200 (29,0)	193 (28,0)	261 (37,9)	186 (27,0)	296 (42,9)	200 (29,0)
250 (480)	196 (28,4)	198 (28,7)	229 (33,2)	198 (28,7)	295 (42,8)	198 (28,7)	192 (27,8)	189 (27,4)	254 (36,8)	182 (26,4)	283 (41,1)	196 (28,4)
300 (570)	183 (26,5)	192 (27,8)	214 (31,0)	192 (27,8)	276 (40,0)	192 (27,8)	183 (26,5)	185 (26,8)	246 (35,7)	177 (25,7)	271 (39,4)	191 (27,7)
350 (660)	169 (24,5)	185 (26,8)	197 (28,6)	185 (26,8)	255 (37,0)	185 (26,8)	175 (25,4)	180 (26,1)	238 (34,5)	171 (24,8)	264 (38,3)	186 (27,0)
425 (800)	161 (23,4)	173 (25,1)	178 (25,8)	173 (25,1)	230 (33,4)	173 (25,1)	161 (23,4)	176 (25,5)	229 (33,2)	161 (23,4)	248 (36,0)	173 (25,1)

13 Stacks, ducts and breeching

13.1 General

13.1.1 This clause applies to the structural design of ducts, breeching and self-supporting vertical steel stacks of circular or conical section.

- **13.1.2** The design of stacks, ducts and breechings shall be in accordance with the applicable provisions of the codes and standards specified by the purchaser and, as a minimum requirement, shall comply with this clause 13. If no specific design code is specified, one of the methods given in annex H should be adopted.

13.2 Design considerations

13.2.1 Stacks shall be self-supporting and shall be bolted to their supporting structure.

- **13.2.2** Stack intermediate construction shall be performed with full-penetration welding or, if agreed by the purchaser, shall be bolted.

13.2.3 Breeching and ducting shall be of welded or bolted construction.

13.2.4 External attachments to stacks shall be seal-welded.

13.2.5 Stacks, ducts and breeching mounted on concrete shall be designed to prevent concrete temperatures in excess of 150 °C (300 °F).

13.2.6 Connections between stacks and flue-gas ducts shall not be welded.

13.2.7 A corrosion-resistant metal cap should be provided at the top of the stack lining refractory to protect its horizontal surface from the weather.

13.2.8 Linings may be required in steel stacks for one or more of the following purposes:

- a) fire protection;
- b) to protect structural shell from gases of excessively high temperature;
- c) corrosion protection;
- d) to maintain the flue-gas temperature at least 20 °C (35 °F) above the acid dew point;
- e) to reduce potential for aerodynamic instability.

13.2.9 The suitability of specialist linings other than refractory should be discussed with the manufacturers but consideration should be given to their strength, flexibility, thermal properties and resistance to chemical attack.

13.2.10 Castable linings shall be secured to stacks, ducts and breeching by suitable anchorage (see 11.3.7).

13.2.11 All openings and connections on the stack, duct or breeching shall be sealed to prevent air or flue-gas leakage.

13.2.12 Breeching shall have a minimum clear distance beyond the last (present or future) convection row of 0,8 m (2,5 feet) for access and flue-gas distribution. At least one take-off shall be provided every 12 m (40 ft) of convection-section tube length.

13.2.13 Stacks, ducts and breeching shall be designed for all applicable load conditions expected during shipment, erection and operation. Snow and ice shall be considered, particularly when the furnace is not in operation. These load conditions shall include, but not be limited to, dead load, wind load, earthquake load, live load and thermal load.

13.2.14 The combination of loads that could occur simultaneously to create the maximum load condition shall be the design load, but in no case shall individual loads create stresses that will exceed those allowed by 13.4. Wind and earthquake loads shall not be considered as acting simultaneously.

13.2.15 The minimum thickness of the stack shell plate shall be 6 mm (1/4 in), including corrosion allowance. The minimum corrosion allowance shall be 1,6 mm (1/16 in).

13.2.16 The minimum number of anchor bolts for any stack shall be eight.

13.2.17 Lifting lugs on stacks, if required, shall be designed for the lifting load as the stack is raised from a horizontal to a vertical position.

13.2.18 Design metal temperature of stacks, ducts and breeching shall be the calculated metal temperature plus 50 °C (90 °F), based on the maximum flue-gas temperature expected for all operating modes with an ambient temperature of 27 °C (80 °F) in still air.

13.2.19 The minimum thickness of breeching and duct plate shall be 5 mm (3/16 in).

13.2.20 Ducts and breeching shall be stiffened to prevent excessive warpage and deflection. Deflection of castable refractory lined ducts and breeching shall be limited to 1/360th of the span. Deflection of other ducts and breeching shall be limited to 1/240th of the span.

13.3 Design methods

Where no specific requirements are given by the purchaser, one of the methods given in H.2 or H.3 of annex H should be adopted

13.4 Static design

13.4.1 All stacks shall be designed as cantilever beam columns.

13.4.2 Linings shall not be considered as contributing to the strength of the stack, duct or breeching.

13.4.3 Discontinuities in the stack shell plate, such as conical-to-cylindrical junctions and non-circular transitions, shall be designed so that the combined membrane and bending stresses in the stack shell or stiffening rings do not exceed 90 % of the minimum yield strength of the respective materials at design temperature.

13.4.4 Openings cut into the stack shall be limited in size to a clear width no greater than two-thirds of the stack diameter. For two openings opposite each other, each chord shall not exceed the stack radius. Openings shall be reinforced to fully restore the required structural capacity of the uncut section.

13.4.5 Apertures in the stack shell plates, other than flue inlets, shall have the corners radiused to a minimum of 10 times the plate thickness.

13.4.6 Changes in cylindrical stack diameters shall be made with cones having an apex angle of 60° or less.

13.4.7 Ring stiffeners provided to carry wind pressure should be designed for the circumferential bending moments.

13.4.8 Circumferential bending moments due to wind pressure may be neglected in unstiffened cylindrical shells if the ratio $R/t \leq 160$, where R is the radius and t is the corroded thickness of the shell.

13.4.9 Stiffening rings are required if $t \leq (5M/9F_{ys})^{0.5}$ and shall be provided as follows:

- a) ring spacing limits: $1 \leq H_s/D < 3$;
- b) ring section modulus required: $Z \geq H_s M / (0.6 F_{yr})$

where

M is the maximum circumferential moment per unit length of shell, in newton metres per metre (N-m/m) [inch-pounds per inch (in-lb/in)];

F_{ys} is the minimum yield strength of shell material at design temperature, in newtons per square millimetre (N/mm²) [pounds per square inch (psi)];

t is the corroded shell thickness, in millimetres (inches);

H_s is the ring spacing, in millimetres (inches);

D is the shell diameter, in millimetres (inches);

Z is the section modulus of ring, in cubic millimetres (cubic inches);

F_{yr} is the minimum yield strength of ring stiffener at the shell design temperature, in newtons per square millimetre (N/mm²) [pounds per square inch (psi)].

13.4.10 Stack deflection due to static wind loads shall not exceed 1 in 200 of stack height, based on the shell plate thickness less 50 % of the corrosion allowance and without considering the presence of a lining.

13.4.11 The permitted deviation (execution tolerance) from the vertical of the steel shell at any level above the base of the erected stack shall be determined from the following formula:

$$\delta = \frac{h}{1000\sqrt{1+50/h}} \quad \text{m}$$

or

$$\delta = \frac{h}{1000\sqrt{1+164/h}} \quad (\text{ft})$$

where

h is the stack height, in metres (feet).

13.5 Wind-induced vibration design

13.5.1 A dynamic analysis shall be made to determine the stack's response to wind and earthquake action. If no specific requirements are given by the purchaser, the methods given in annex H should be adopted.

13.5.2 If the critical wind speed for the first mode of vibration of the stack is 1,25 times higher than the maximum (hourly mean) design wind speed (evaluated at the top of the stack), dynamic loads resulting from cross-wind response need not be included in the design load.

13.5.3 If analysis indicates that excessive vibrations due to cross-winds are possible, one of the following methods to reduce vortex-induced amplitudes shall be used.

- a) Increase mass and structural damping characteristics (e.g. use of refractory lining).
- b) Use a mass damper (e.g. tuned pendulum damper).
- c) Use aerodynamic devices (e.g. helical or vertical strakes as described in 13.5.4 and 13.5.5 or staggered vertical plates as described in 13.5.6), the choice of which shall be specified or agreed by the purchaser. Annex H gives recommendations regarding the application of spoilers or strakes.
- d) Modify stack length and/or diameter until acceptable vibration characteristics are achieved.

13.5.4 When strakes are required to disrupt wind-induced vibration, they shall be used on at least the upper third of the stack height.

13.5.5 Helical strakes shall consist of three rectangular strakes of thickness 6 mm (1/4 in) at 120° spacing with a pitch of five diameters and a projection of 0,1 diameters.

13.5.6 Staggered vertical plates shall be not less than 6 mm (1/4 in) thick and not more than 1,5 m (5 ft) long. Three strakes shall be placed at 120° around the stack and shall project 0,10 diameters from the outside of the stack. Adjacent levels of strakes shall be staggered 30° from each other.

13.5.7 Where a stack is positioned within close proximity of other tall structures, consideration should be given to the possibility of buffeting effects.

13.5.8 Where a stack is positioned adjacent to another stack or tall cylindrical vessel, the minimum recommended spacing between centres is $4d$, where d is the largest diameter of the adjacent structures. Interference effects may be neglected for spacing between centres of greater than $15d$.

13.5.9 For a stack downwind of an adjacent stack or a tall vessel, interference effects shall be accounted for by an increase in wind load.

13.6 Materials

The material of the stack, breeching and duct shall be adequate for all load conditions at the lowest specified ambient temperature when the furnace is not in operation (see 12.5).

14 Burners and auxiliary equipment

14.1 Burners

14.1.1 Burner design, selection, spacing, location, installation and operation shall ensure against flame impingement on tubes, tube supports and flame exiting the radiant section of the heater throughout the entire operating range of the burners. The location and operation of burners shall ensure complete combustion within the radiant section of the heater.

14.1.2 Burners shall be designed in accordance with all local and national statutes and regulations.

14.1.3 For burner clearances, the data given in Table 11 shall be used for natural-draught burners and in Table 12 for forced-draught burners.

14.1.4 In addition to 14.1.3 above, the following shall apply.

- a) The number and size of burners shall ensure that the visible flame length is a maximum of two-thirds of the radiant section height.
- b) For horizontal opposed firing, the minimum visible clearance between directly opposed firing flame tips shall be 1,2 m (4 ft).

14.1.5 For burners outside the range given in Table 11 and Table 12, verifiable data shall be obtained before any design is finalized. For high heat releases, see 14.1.8 and 14.1.10.

14.1.6 For other types of burner (e.g. fan-shaped flame or radiant-wall flame), vendor or other verifiable data shall be obtained.

14.1.7 All burners shall be sized for a maximum heat release at the design excess air based on the following:

- a) five or fewer burners, 120 % of normal heat release at design conditions;
- b) six or seven burners, 115 % of normal heat release at design conditions;
- c) eight or more burners, 110 % of normal heat release at design conditions.

- **14.1.8** For liquid-fuel-fired heaters with a maximum heat release greater than 4,4 MW (15×10^6 Btu/h), a minimum of three burners shall be used. Alternatively, if specified or agreed by the purchaser, a single burner with auxiliary guns may be used to permit gun maintenance without shutting down or upsetting the process.

14.1.9 Gas pilots shall be provided for each burner.