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PROCESS DESIGN OF FURNACES

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standard and Specification is intended to cover minimum requirements for process design of furnaces.

The requirements outlined herein are supplementary to the specifications listed on the individual fired heater data sheets.

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. **API (American Petroleum Institute)**

   API Standard 560 "Fired Heaters for General Refinery Services"
   API Standard 630 "Tube and Header Dimensions for Fired Heaters for Refinery Services"

DEFINITIONS AND TERMINOLOGY

Air Heater or Air Preheaters - An air heater or air preheater is a heat transfer apparatus through which combustion air is passed and heated by a medium of higher temperature, such as the products of combustion, steam or other fluid.

Arch - An arch is the flat or sloped portion of the heater radiant section opposite the floor.

Atomizer - An atomizer is a device used to reduce a fluid to a fine spray. Atomization means are normally either steam, air or mechanical.

Balanced Draft Heater - Combustion air to a balanced draft heater is supplied by a fan and the flue gases are removed by a fan.

Breeching - Breeching is the enclosure in which flue gases are collected after the last convection coil for transmission to the stack or the outlet duct work.

Damper - A damper is a device for introducing a variable resistance for regulating the volumetric flow of gas or air.

Defects - All items which require replacement or repair but could not have been replaced or repaired before take over and in no way hinder or affect the requirements for substantial completion.

Direct Regenerative-Type Air Preheater - A direct regenerative-type air preheater is a counter-flow gas-to-air heat transfer device that has a compartmented rotor and is contained in a rotor housing supported by bearings. Each of the compartments is filled with metallic heating elements. The rotor is slowly rotated, alternately through the gas and air streams. Hot flue gas flows through one side of the rotor and heats the elements. Air flows through the other side where the stored heat is released to the air stream. The air and gas flows are separated by diaphragms in the rotor as well as seals between the rotor and the rotor housing.

Direct Recuperative-Type Air Preheater - A direct recuperative-type air preheater is a gas-to-air heat transfer device that consists of a bundle of tubes expanded into a tube sheet, or a block of flow elements and enclosed in a casing. Flue gas or air can flow through the tubes. Extended surfaces are commonly used.

Draft - Draft is the negative pressure (vacuum) of the flue gas measured at any point in the heater, expressed in millimeters of water column (mm H_2O) and/or kilopascals (kPa).

Efficiency, Fuel - Efficiency, fuel refers to the heat absorbed divided by the net heat of combustion of the fuel as heat input, expressed as a percentage.

Efficiency, Thermal - Efficiency, thermal refers to the total heat absorbed divided by total heat input, expressed as a percentage.

Excess Air - Excess air is the amount of air above the stoichiometric requirement for complete combustion, expressed as a percentage.

Extended Surface - The extended surface refers to the heat transfer surface in the form of fins or studs, added to heat absorbing elements.

Extension Ratio - Extension ratio is the ratio of total outside exposed surface to the outside surface of the bare tube.

Flux Density, Average - Flux density, average is the heat absorbed divided by the exposed heating surface of the coil section. Average flux density for an extended surface tube shall be indicated on a total surface basis with the extension ratio noted, expressed in kilowatts per square meter (kW/m^2).

Flux Density, Maximum - Flux density, maximum is the maximum local heat transfer rate in the coil section, expressed in kilowatts per square meter (kW/m^2).

Forced Draft Heater - Forced draft heater is a heater in which the combustion air is supplied by a fan and the flue gases are removed by the stack effect.

Header - Header, sometimes called a return bend, is the common term for a 180-degree cast or wrought fitting that connects two or more tubes.

Header Box - The header box is the internally insulated structural compartment, separated from the flue gas stream, which is used to enclose a number of headers or manifold. Access is afforded by means of hinged doors or removable panels.

Heat Absorption - Heat absorption is the total heat absorbed by the coil(s), excluding any combustion air preheat, expressed in watts (W).

Heat Release - Heat release is the total heat liberated from the specified fuel, using the lower heating value of the fuel, expressed in watts (W).

Heating Value, Higher (HHV) - Heating value, higher is the total heat obtained from the combustion of a specified fuel at 15°C (60°F), expressed in kilojoules per kilogram (kJ/kg) or per cubic meter (kJ/m^3).

Heating Value, Lower (LHV) - Heating value, lower is the higher heating value minus the latent heat of vaporization of the water formed by combustion of hydrogen in the fuel, also called the net heating value, expressed in kilojoules per kilogram (kJ/kg) or per cubic meter (kJ/m^3)

Indirect-Type Air Preheater - An indirect-type air preheater is a fluid-to-air heat transfer device. The heat transfer can be accomplished by using a heat transfer fluid, a process stream or a utility stream which has been heated by the flue gas, or other means.

Plenum - A plenum, sometimes called a windbox, is a chamber surrounding the burners and is used to distribute air to the burners or reduce combustion noise.

Radiation Loss or Setting Loss - Radiation loss or setting loss is the heat lost to the surrounding from the casing of the heater and the ducts and auxiliary equipment when heat recovery systems are used, expressed as percent of heat release.

Setting - The setting is the heater casing, brickwork, refractory and insulation, including the tiebacks or anchors.

Volumetric Heat Release - Volumetric heat release is the heat released divided by the net volume of the radiant section, excluding the coils and refractory dividing walls, expressed in kilowatts per cubic meter (kW/m^3).

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
ANSI	American National Standard Institute.
API	American Petroleum Institute.
ASME	American Society of Mechanical Engineers.
ASTM	American Society for Testing and Materials.
APH	Air Preheater.
bbl/sd	Barrels Per Stream Days.
BEDD	Basic Engineering Design Data.
BP	British Petroleum.
BSI	British Standards Institution.

CCR	Central Control Room.
DN	Diameter Nominal, in (mm).
Eq	Equation.
FDF	Forced Draft Fan.
FE	Flow Element.
FSLL	Flow Switch Low Low.
HC	Hydrocarbon.
HHV	Higher Heating Value.
IDF	Induced Draft Fan.
L/D	Tube Length/Tube Circle Diameter.
LHV	Lower Heating Value.
MW	Molecular Mass (Weight).
NAFM	National Association of Fan Manufacturers.
NPS	Nominal Pipe Size, in (inch).
PB	Push Button.
PCV	Pressure Control Valve.
PDIC	Pressure Differential Indicator Controller.
PDSLL	Pressure Differential Switch Low Low.
P & IDs	Piping and Instrument Diagrams.
PG	Pressure Gage.
PSHH	Pressure Switch High High.
PIC	Pressure Indicator Controller.
PSLL	Pressure Switch Low Low.
PT	Pressure Transmitter.
PTC	Performance Test Code.
PV	Pressure Valve.
PY	I/P Converter.
SAH	Steam Air Heater.
SS	Stainless Steel.
SUS	Saybolt Universal Seconds.
Th	Traced hot.
TSHH	Temperature Switch High High.
V/F	Vapor/Feed.
WC	Water Column.

UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

DESIGN REQUIREMENTS OF FURNACE

Design Conditions

1. Of the several operating cases, the one in which the heater duty is the highest, shall be regarded as the normal case.
2. Unless otherwise specified, the design duty shall be 110% of the furnace duty in the normal case mentioned above.
3. The design conditions shall be as follows, depending on the service of the furnace:
   a. Charge heaters:
      - The allowance for the design duty shall be regarded as a consideration for the fouling of the heat exchanger train and the furnace inlet temperature shall be lowered in proportion to the design duty allowance.
      - If the case regarded as the highest duty is an extremely rare operation, the design duty may be 100% of the furnace duty in the highest duty case upon Company's approval.

   b. Reboilers and hot oil heaters:

      The furnace charge flow rate shall be increased in proportion to the design duty allowance.

   c. Thermal cracking heaters:

      The design duty allowance shall be regarded as an allowance for the cracking in the furnace and the furnace outlet temperature shall be raised in proportion to the allowance.

Furnace Turndown

Unless otherwise specified, the furnace turndown ratio shall be 50% of the normal condition.

Furnace Outlet Temperature

1. In cases where the fluid thermal decomposition temperature is known, the limit of the furnace tube inside film temperature must be specified.
2. For determination of furnace maximum outlet temperature, charge oil decomposition and discoloration conditions shall also be considered.

Velocity Limitation

The velocity limitation in the furnace outlet line should be according to the Company's requirements.

Fouling Factor

Unless otherwise specified, for usual furnaces the following fouling factors may be used:

SERVICE	FOULING FACTOR ($m^2.°C/W$)
Crude charge heater with desalter	5.283E-4
Crude charge heater without desalter	7.044E-4
Vacuum charge heater	8.805E-4
Hydrodesulfurization reactor charge	
Naphtha	3.522E-4
Kerosene or gasoil	5.283E-4
Naphtha liquid with sulfur	3.522E-4
Naphtha liquid without sulfur	1.761E-4
Kerosene with sulfur	5.283E-4
Kerosene without sulfur	3.522E-4
Recycle gas and HC vapor	1.761E-4

Pressure Drop

In cases where fluid coking is conceivable due to high furnace outlet temperature, the pressure drop shall be calculated for the clean and fouled cases. Unless otherwise specified, the tube coking thickness shall be 3.2 mm (1/8") in the fouled case.

In the case of services where vaporization will occur in the furnace tubes, the flash curves and fluid temperature physical property chart (for instance, API, MW, etc.) shall be attached to the data sheet.

Thermal Design

1. Calculated and actual efficiencies shall be as required by the process and shown on the data sheets and shall be based on design duty, lower heating value of the primary fuel, relevant excess air for gas and oil firing in natural or forced draft heaters and shall include a maximum radiation loss of 1.5 percent of the calculated (normal) heat release.

Heaters employing air preheat systems shall include a maximum radiation loss of 2.5 percent of the total heat input.

2. The average radiant heat flux specified on the data sheets is defined as the quotient of total heat absorbed by the radiant tubes divided by the total outside circumferential tube area inside the firebox, including any fitting inside the firebox. The rows of convection tubes exposed to direct radiation shall be considered as being in the radiant section and the maximum radiation heat absorption rate shall apply to these tubes, irrespective of whether extended surface element are used or not.
3. The maximum radiant heat flux density is defined as the maximum heat rate to any portion of any radiant tube. The rate shall be calculated for the front 60° of the tube surface. The density is not to be considered as operating average flux density for any given length of tube surface. The maximum tube metal temperature shall be calculated on the basis of the maximum flux density.
4. Process design conditions are shown on the individual fired heater data sheets. If the fired heater is intended for several cases of operation, the design conditions and operating conditions in each case shall be shown therein.
5. Vendor shall specify the amount of excess air and stack temperature when operating at the guaranteed efficiency.
6. Unless otherwise specified, determination of the tube length shall be based on the following criteria.

   <u>Where:</u>

   Lr is total effective length of radiant tubes;
   D is pitch circle of diameter tubes (tube circle diameter);
   Lc is total effective length of convection tubes.

   a. Maximum L/D values for vertical cylindrical heaters based on design heat absorption rates shall be:

      Lr/D 2 for design heat absorption rate up to 3 MW.

      Lr/D 2.5 for design heat absorption rate of 3-6 MW.

      Lr/D 2.75 for design heat absorption rate over 6 MW.

   b. For horizontal tube heaters Lr = Lc

      For horizontal end firing Lr = Lc = 15 m max. Eq. (1)

   c. Unless otherwise specified, the maximum length of vertical radiant tubes shall be 18 m (60 ft).

7. Determination of minimum firing distances

   Heater dimensions shall meet the following restrictions. The minimum distances from the centerlines of the burners (outer burner circle for vertical cylindrical heaters) to the centerline of the tubes shall be as follows:

   a. For vertical firing:

BURNER SIZE MAXIMUM LIBERATION (MW)	DISTANCE TO ROOF TUBES (mm)	DISTANCE TO WALL TUBES (mm)
0.6	1800	750
1.2	3000	900
1.8	4200	1050
2.4	6000	1200
Over	Add 1200 mm for each added 1.2 MW	Add 150 mm for each added 1.2 MW

   For horizontal tubes, the vertical distance from heater floor to the bottom tube shall not be less than 610 mm.

   b. For horizontal firing of burners up to 1.2 MW maximum liberation, minimum distance to wall or roof tubes shall be 1500 mm. Add 150 mm for each additional 1.2 MW release larger burners.

8. A prime rule of heater design is that there should never be greater than atmospheric pressure at any point within the heater structure, since as the pressure within the furnace becomes greater than atmosphere, cooling air is no longer drawn in through the various cracks and apertures in the furnace, instead, there is outward movement of hot gases to cause loss of fuel as well as serious overheating of steel elements in the furnace structure, which can result in the failure of various parts or there can be serious wrapage or corrosion.

9. Heaters shall be designed for uniform heat distribution, multipass heaters shall be designed for hydraulic and thermal symmetry of all passes.

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

11. Unless otherwise specified by the Company, calculated efficiencies for natural draft operation shall be based on 10 percent excess air when fuel gas is the primary fuel and 15 percent excess air when oil is the primary fuel. In the case of forced draft operation, calculated efficiencies shall be based on 5 percent excess air for fuel gas and 10 percent excess air for fuel oil.