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Revision Memo

12/96

1. Consolidated English and Metric Units.
2. Updated references.
3. Revised **Table 1** to reflect current practices.

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SCOPE

This subsection describes the different types of fired process heaters which are available and gives guidelines for selecting and specifying the fired heater for a specific service. Fired heater design is covered in other subsections.

REFERENCES

DESIGN PRACTICES (Besides Other Subsections of this Section)

[Section XIV](#) Fluid Flow

♦ [Section XV](#) Safety in Plant Design

♦ INTERNATIONAL PRACTICES

[IP 3-4-1](#) Piping for Fired Equipment

[IP 7-1-1](#) Fired Heaters

[IP 7-3-1](#) Sootblowers for Fired Equipment

[IP 7-4-1](#) Burners for Fired Heaters

[IP 7-5-1](#) Coils for Fired Heaters and Boilers

[IP 7-8-1](#) Dampers and Guillotines for Fired Equipment

[IP 7-9-1](#) Expansion Joints for Fired Equipment

[IP 15-1-1](#) Instrumentation for Fired Heaters

[IP 18-3-2](#) Statically Cast Steel and Alloy Pressure Containing Parts, and Tube Supports for Fired Heaters

[IP 18-3-3](#) Centrifugally Cast High Alloy Tubes for Fired Heaters other than Steam Cracking Reactors

[IP 19-3-3](#) Linings for Fired Heaters

♦ OTHER LITERATURE

API 560, Fired Heaters for General Refinery Services

API 530, Recommended Practice for Calculation of Heater Tube Thickness in Petroleum Refineries

Report EE.70E.75, Pipestill Furnace Turndown

Guide to Boiler and Fired Heater Turndown and Excess Air Reduction

Application Technology Set Catalog (ATS CAT)

Exxon Engineering Cost Estimating Manual

Exxon Refinery Construction Materials Manual

BACKGROUND

The heating of a process fluid in a fired heater is accomplished through a combination of radiation and convection heat transfer. The usual flow pattern of the process fluid is countercurrent to the flue gas; i.e., the process fluid passes first through the convection section and then through the radiant section of the fired heater, whereas the flue gas travels in the other direction. This arrangement yields a higher fired heater efficiency (lower stack gas temperature) than would be the case with concurrent flow.

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BACKGROUND (Cont)

In the radiant section, heat is transferred to the process fluid mainly by radiation from high-temperature flue gas which results from combustion of fuel in the fire box. Some heat is also transferred here by convection. As the flue gas in the radiant section gives up its heat and becomes cooler, heat transfer by radiation requires progressively more tube area, therefore becoming progressively less economical. For this reason, the transition to the convection section is made while the flue gas is still relatively hot.

In the convection section, heat transfer is mainly by convection, although a small amount of radiant heat transfer occurs here also. After all of the heat which can be economically recovered has been transferred to the process fluid, the flue gas leaves the fired heater and passes through a stack to the atmosphere.

Fired heaters fall into two main categories: process and pyrolysis fired heaters.

PROCESS FIRED HEATERS (CONVENTIONAL)

These fired heaters provide heat which is utilized in downstream equipment. Typical examples are pipestills, reactor preheaters (hydrofiners and POWERFORMING units), and reboilers. Indirect heating systems, such as hot oil belts, also use process fired heaters.

PYROLYSIS FIRED HEATERS

These heaters provide the energy for endothermic chemical reactions taking place inside fired heater tubes. Steam Crackers and Steam Reformers are the two main examples. Many considerations and problems in the design and operation of these heaters are similar to those of conventional heaters. Pyrolysis heaters usually operate at high temperatures and have many special considerations. [Design Practice Subsection E](#) covers the design of Exxon Steam Reformers. Steam Cracking heaters are not covered in the Exxon Engineering Design Practices.

Some fired heaters such as visbreakers and thermal crackers, are considered to be process heaters even though they have chemical reactions taking place inside the tubes. Their temperatures are low, compared to those of pyrolysis heaters, and apart from the cracking calculations (consult the Heat Transfer Equipment Section of EETD), the designs closely resemble those for process heaters.

TYPES OF SPECIFICATIONS

Two types of documents are used for specifying fired heaters: design specifications or duty specifications. In a design specification, all of the major variables which affect performance have been determined by the designer and are specified. The fired heater vendor must then provide the detailed mechanical design. In a duty specification, only the service requirements (e.g., heat duty and inlet and outlet conditions) of the equipment are given. The vendor then provides both the process and mechanical designs.

Items covered in each type of specification are given in [Tables 1](#) and [2](#). Fired Heater Data Sheets, ER&E developed or API 560, may be used to present the information required by either type of specification. Most of the fired heaters specified by Exxon Engineering are covered by a design specification. TO PROTECT PROPRIETARY TECHNOLOGY, PROCESS INFORMATION FOR FIRED HEATERS COVERED BY DESIGN SPECIFICATIONS SHALL NOT BE DIVULGED TO THE FIRED HEATER VENDOR BEFORE THE APPROPRIATE SECRECY AGREEMENTS HAVE BEEN EXECUTED.

DEFINITIONS

(SEE ALSO [FIGURES 1](#) THROUGH [6](#))

Air Preheater. A heat exchanger which heats the air required for combustion by exchanging heat with the flue gases leaving the convection section.

Arch. The overhead (usually flat) portion of the radiant section, supported from above.

Box. The burners and tubes are enclosed in the fire box, which consists of a structure, refractory lining and tube supports.

Breeching. The hood which collects the flue gas at the convection section exit, for transmission to the stack.

Bridgwall Temperature. The temperature of the flue gas leaving the radiant section. The term comes from the old horizontal box heaters, where a bridgwall physically separated the radiant and convection sections.

Bulk Temperature. The average temperature of the process fluid at any tube cross-section.

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DEFINITIONS (Cont)
(SEE ALSO **FIGURES 1** THROUGH **6**)

Burner. A device for mixing fuel and air for combustion.

Casing. A steel sheathing which encloses the heater box and makes it essentially air-tight.

Cell. A portion of the radiant section, separated from other cells by tubes or a refractory wall. Also called a “**zone**”.

Center Wall. A refractory wall in the radiant section, which divides it into two separate cells.

Coil. A series of straight tube lengths connected by 180° return bends, forming a continuous path through which the process fluid passes and is heated.

Convection Section. The portion of a heater, consisting of a bank of tubes, which receives heat from the hot flue gases, mainly by convection.

Conversion. The fraction of feed converted into a desired product, usually expressed as LV%. Applied mainly to Visbreaker and Thermal Cracker Fired Heaters.

Corbelling. Narrow ledges extending from the convection section side walls to prevent flue gas from flowing preferentially up the side of the convection section, between the wall and the nearest tubes, thereby bypassing the tube bank.

Critical Velocity. A fluid velocity equal to the velocity of sound through the fluid at its temperature and pressure. Also called “**sonic velocity**”.

Crossover. Piping which transfers the process fluid either externally or internally from one section of the heater to another.

Damper. A device to regulate flow of gas through a stack or duct and to control draft in a heater. A typical damper consists of one or more flat plates connected to a shaft(s) which can be rotated.

Draft. The negative pressure (vacuum) at a given point inside the heater, usually expressed in inches of water.

Excess Air. The percentage of air in the heater in excess of the stoichiometric amount required for combustion.

Extended Surface. Surface added to the outside of bare tubes in the convection section to provide more heat transfer area. This may consist of cylindrical studs butt-welded to the tube or fins continuously wound around and welded to the tube.

Film. A thin fluid layer adjacent to a pipe wall which remains in laminar flow, even when the bulk flow is turbulent. The velocity profile in the film is approximately linear, with zero velocity existing at the wall.

Film Coefficient. The convective heat transfer coefficient of the film.

Film Temperature. The maximum temperature in the film, at the tube wall.

Fire Box. A term used to describe the structure which surrounds the radiant coils and into which the burners protrude.

Flue Gas. A mixture of gaseous products resulting from combustion of the fuel.

Fouling. The building up of a film of dirt, ash, soot or coke on heat transfer surfaces, resulting in increased resistance to heat flow.

Forced Draft. Use of a fan to supply combustion air to the burners and to overcome the pressure drop through the burners. This is in contrast to natural draft, where the buoyancy of the column of hot flue gas in the stack and heater provides the “suction” to pull combustion air into the burners.

Fired Heater Efficiency. The ratio of heat absorbed to heat fired, on a lower heating value basis.

Gross Fuel. The total fuel fired in the heater, including all losses (usually expressed in lb/hr or kg/hr).

Gross Heating Value. See **higher heating value**.

Header. The fitting which connects two tubes in a coil. In common usage, “header” refers to cast or forged 180° “U-bends” (“return bends”).

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DEFINITIONS (Cont)
(SEE ALSO **FIGURES 1** THROUGH **6**)

Header Box. The compartment at the end of the convection section where the headers are located. There is no flue gas flow in the header box, since it is separated from the inside of the heater by an insulated tube sheet. Header boxes are sometimes also used in the radiant section.

Heat Available. The heat absorbed from the products of combustion (flue gas) as they are cooled from the flame temperature to a given flue gas temperature.

Heat Density. The rate of heat transfer per unit area to a tube, usually based on total outside surface area. Typical units are Btu/hr-sq. ft (w/m²). Also called “**heat flux**”.

Heat Duty. The total heat absorbed by the process fluid, usually expressed in MBtu/hr (MW). Total fired heater duty is the sum of heat transferred to all process streams, including auxiliary services such as steam superheaters and drier coils.

Heat Fired. The total heat released in the heater, equal to gross fuel times lower heating value (LHV) of the fuel. Usually expressed in MBtu/hr (MW).

Higher Heating Value (HHV). The theoretical heat of combustion of a fuel, when the water formed is considered as a liquid (credit taken for its heat of condensation). Also called “**gross heating value**”.

Hip Section. The transition zone at the top of the radiant section in cabin type heaters. The wall of this section is usually at a 45 degree angle.

Induced Draft. Use of a fan to provide the additional draft required over that supplied by the stack, to draw the flue gas through the convection section, and any downstream heat recovery equipment (i.e., air preheater).

Inspection Doors. Openings in the convection section sidewalls to allow inspection of tubes, extended surfaces and supports, when the heater is out of service.

Lower Heating Value (LHV). The theoretical heat of combustion of a fuel, when no credit is taken for the heat of condensation of water in the flue gas. Also called “**net heating value**”. Usually expressed in Btu/lb (kJ/kg).

Manifold. A pipe connected to several parallel passes and used to distribute or collect fluid from these passes.

Mass Velocity. The mass flow rate per unit of flow area through the coil. Typical units are lb/s-sq. ft (kg/s-m²).

Natural Draft. System in which the draft required to move combustion air into the heater and flue gas through the heater and out the stack is provided by stack effect alone.

Net Fuel. The fuel which would be required in the heater if there were no radiation losses. Usually expressed in lb/hr (kg/hr).

NPS. Abbreviation for “**Nominal Pipe Size**”.

Observation Doors. Openings in the radiant section floor and at selected points along the walls, to permit viewing of tubes, supports, and burners.

One-Side Fired Tubes. Radiant section tubes located adjacent to a heater wall have only one side directly exposed to a burner flame. Radiation to the back side of the tubes is by reflection/reradiation from the refractory wall.

Pass. A coil which transports the process fluid from fired heater inlet to outlet. The total process fluid can be transported through the heater by one or more parallel passes.

Peepholes. Small observation ports usually placed in the radiant section floor and/or arch to permit viewing of tubes, supports and burners. They are usually glass covered.

Radiant Section. The section of the fired heater in which heat is transferred to the heater tubes primarily by radiation from high-temperature flue gas.

Service Factor. A measure of the continuity of operation, generally expressed as the ratio of total running days for a given time period to the total calendar days in the period.

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DEFINITIONS (Cont)
(SEE ALSO **FIGURES 1** THROUGH **6**)

Setting. The refractory insulation on the inside of the heater box.

Shield Section. The first two tube rows of the convection section. These tubes are exposed to direct radiation from the radiant section and usually receive about half of their heat in this manner. They are usually made of more resistant material than the rest of the tubes in the convection section. Extended surfaces are **not** used in this section.

Sootblower. A steam lance (usually movable) in the convection section for blowing soot and ash from the tubes using high-pressure steam.

Stack. A cylindrical steel, concrete or brick shell which carries flue gas to the atmosphere and provides necessary draft.

Stack Effect. The difference (buoyancy) between the weight of a column of high-temperature gases inside the heater and/or stack and the weight of an equivalent column of external air, usually expressed in inches of water per foot of height.

Stack Temperature. The temperature of the flue gas as it leaves the convection section, or air preheater directly upstream of the stack.

Transfer Line. Piping used to connect the fired heater outlet to downstream processing equipment (tower, reactor, etc.).

Tube Guide. Device used to guide thermal movement of tubes.

Tube Sheet. A large tube support plate located in the convection section and supporting a number of tubes. The end supports are usually carbon steel or low-alloy steel and make up one side of the header box. The inside of the end supports, which is exposed to the flue gas, is insulated. Intermediate supports are exposed to flue gas on both sides and are fabricated of a suitable alloy material, usually castings.

Tube Support. A metal part which supports the weight of the tube.

Turndown. Reduced operating conditions compared to design conditions. This usually refers to reduced heat duty, which may be the result of reduced throughput and/or reduced enthalpy requirements.

Two-Side Fired Tubes. Radiant section tubes which are exposed on both sides to direct radiation from the burners.

TYPES OF FIRED HEATERS

Many fired heater types, or arrangements, are available and have been used over the years. These heaters are all made up of four basic components: box, burners, coil and stack. The fired process heaters described below are currently the types most commonly found in Exxon refineries and chemical plants.

VERTICAL-CYLINDRICAL FIRED HEATERS

Figures 1 and **2** show cross-sectional views of typical vertical-cylindrical (VC) fired heaters. These heaters are probably the most common in use today and are used for heat duties up to about 150 MBtu/hr (45 MW). In the radiant section, tubes stand or hang vertically in a circle around the floor-mounted burners. Thus, firing is parallel to the radiant section tubes.

Vertical-cylindrical heaters are designed both with and without a convection section. The all-radiant heater (**Figure 1A**) is inexpensive, but since the temperature of flue gases leaving the heater is high, 1500 – 1800°F (815 – 980°C), it has a very low efficiency. A convection section can usually be justified, except for the very smallest heaters less than about 5 MBtu/hr (1.5 MW), heaters infrequently operated, or in locations where fuel costs are extremely low.

Most vertical-cylindrical fired heaters now built have a horizontal convection section located above the radiant section (**Figure 2**). Flue gases flow upwards through the convection bank and then to the stack. The shield section consists of the bottom two rows of tubes in the convection section.

Some older vertical-cylindrical fired heaters have vertical convection sections (**Figure 1B**). Often the same tube is used for both radiant and convection service (integral convection section). The convection portion of the tube usually has some form of extended surface to increase the convection heat transfer rate. Only gas or distillate fuels should be fired in this type heater, since the convection section is almost impossible to clean. This type of fired heater has not been built since the mid-1960's.

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TYPES OF FIRED HEATERS (Cont)

HORIZONTAL TUBE CABIN FIRED HEATERS

Figure 3 shows end and side views of a typical cabin fired heater. The radiant section includes horizontal tube surface on the side walls and the sloping roof of the cabin. The convection section extends over the entire length of the radiant section. Burners are floor-mounted in a row down the center of the cabin and are fired vertically. Thus, firing is normal to both radiant and convection tubes.

Horizontal tube cabin fired heaters have been built in sizes up to about 500 MBtu/hr (145 MW) heat absorbed. However, in small sizes under about 120 MBtu/hr (35 MW), vertical cylindrical fired heaters are usually more economical, and in sizes larger than about 150 MBtu/hr (45 MW), the vertical tube box fired heater is generally more economical. Also, both vertical tube type fired heaters require less plot area. Therefore, except in special cases, horizontal tube cabin fired heaters are no longer being designed by Exxon Engineering.

Variations of the cabin fired heater arrangements are made for certain applications, as illustrated in **Figure 4**. Cabin fired heaters with a center wall (**Figures 4A and B**) can be used for the following services:

1. For large fired heaters, the use of an air-cooled center wall permits about twice the surface for a given tube length. This configuration is usually used when tubes in a single radiant zone would be over about 80 ft (24 m) long, or the radiant zone over 40 ft (12 m) high.
2. Where two separate heating zones (i.e., two or more separately controlled services) are required in the radiant section. Depending upon the heater size, the center wall may or may not be covered with tubes. The different services must be compatible, since to some extent the firing in one section will affect heater transfer in the other section. The maximum turndown of one service is to about 75% of design with the other service at full capacity, if both services use the convection section (or to about 50% of design if one is in all-radiant service). If one service is taken off stream, the heater must be completely shut down or some other fluid circulated through the off-stream section to prevent tube burnout.

HOOP-TUBE CABIN FIRED HEATERS

In all-vapor flow, non-coking services where low coil pressure drop is desired (such as POWERFORMING units), cabin fired heaters with vertically oriented, bent, or "hoop", tubes offer considerable savings in investment (**Figures 4C and D**). This arrangement permits a low process mass velocity to be used, because of the many parallel flow passes, without maldistribution of flow.

For POWERFORMING heaters, the radiant section consists of separate zones for preheat and for each reheat duty. These zones are separated by free-standing brick walls. Flue gases from all of the radiant zones pass through a common convection section, which in the past has been utilized for preheat service only. In such a heater, variations in operating conditions of the individual services should be carefully considered, since the reheat zones are also providing heat to the preheat convection coil. More recently, with low pressure POWERFORMING, the entire process duty will be absorbed in the radiant section and the convection section used for a separate service(s). This is due to the relatively high/costly pressure drop of the convection coil. POWERFORMING heaters of the hoop tube type have been built in sizes from about 70 to 400 MBtu/hr (20 to 120 MW) total heat absorbed.

VERTICAL TUBE BOX FIRED HEATERS

The Exxon High Intensity Heater is a proprietary vertical tube box fired heater design and has substantial advantages over the designs of our competitors. TO PROTECT THIS PROPRIETARY TECHNOLOGY, CARE MUST BE TAKEN TO INSURE THAT ONLY CONTRACTORS AND FIRED HEATER VENDORS WHO HAVE SIGNED APPROPRIATE CONFIDENTIALITY AGREEMENTS ARE GIVEN INFORMATION ON THE VERTICAL TUBE BOX FIRED HEATER.

Figure 5 shows a typical vertical tube box fired heater. In the radiant section, tubes stand vertically along all four walls. These tubes are fired from one side, the same as in vertical-cylindrical and cabin fired heaters. In addition, rows of standing vertical tubes running across the box are fired on both sides by the floor-mounted burners. These two-side fired tubes have a 50% greater heat input than the wall tubes, although the peak heat density is the same as for the wall tubes.

The addition of the two-side fired tubes shortens the radiant coil and results in a significant decrease in radiant box volume, compared to horizontal tube cabin heaters. Each tube pass has an equal number of both wall and center tubes, so that heat distribution between passes is uniform. This heater is particularly well suited for the large forced-draft burners now in general usage. Two to four burners provide the required heat input to each cell and usually set the box dimensions. A horizontal convection section running the entire length of the heater is located above the radiant section.

Variations of the vertical tube box fired heater arrangement are occasionally used. The most common variation consists of installing only the two-side fired center tubes. These tubes are usually installed in a number of rows across the box, normal to the convection section. They may also be installed in two rows parallel to the convection section, extending the entire length of the heater. The latter arrangement is like that used in steam reformer fired heaters.