



UOP LLC
25 East Algonquin Road
Des Plaines, Illinois 60017-5017, USA

STANDARD SPECIFICATION

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2. GENERAL

2.1 Scope

- a. This Standard Specification covers the general requirements for the design and fabrication of fired heaters.
- b. Exceptions or variations shown in the UOP Project Specifications take precedence over requirements shown herein.

2.2 References

Unless noted below, use the edition and addenda of each referenced document current on the date of this Standard Specification. When a referenced document incorporates another document, use the edition of that document required by the referenced document.

- a. International Organization for Standardization (ISO) 13705, "Petroleum and natural gas industries – Fired heaters for general refinery service" / American Petroleum Institute (API) Std 560, "Fired Heaters for General Refinery Service"
- b. ISO 13704, "Petroleum and natural gas industries – Calculation of heater-tube thickness in petroleum refineries" / API Std 530, "Calculation of Heater-Tube Thickness in Petroleum Refineries"
- c. API RP 535, "Burners for Fired Heaters in General Refinery Services"
- d. API RP 936, "Refractory Installation Quality Control Guidelines – Inspection and Testing Monolithic Refractory Linings and Materials"
- e. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section I, "Rules for Construction of Power Boilers"
- f. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, "Rules for Construction of Pressure Vessels"
- g. ASME B31.3, "Process Piping"
- h. ASME B16.5, "Pipe Flanges and Flanged Fittings, NPS ½ Through NPS 24"
- i. ASME B16.47, "Large Diameter Steel Flanges, NPS 26 Through NPS 60"
- j. ASME B46.1, "Surface Texture (Surface Roughness, Waviness, and Lay)"
- k. ASME B16.20, "Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed"



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- l. American Society of Testing Materials (ASTM) Specifications A 105, A 106, A 182, A 192, A 193, A 194, A 213, A 216, A 217, A 234, A 240, A 283, A 297, A 312, A 335, A 351, A 358, A 376, A 403, A 450, A 530, A 560, A 691, B 163, B 366, B 407, B 564, C 27, C 401, E 112, and E 446
- m. National, state, and local governmental regulations and laws

3. LAYOUT & DESIGN

- a. The design, fabrication and assembly of the heater components shall comply with ISO 13705 / API 560, except where modified by either the UOP Project Specifications or UOP Standard Specifications.
- b. Process tubes shall not be larger than NPS 8. NPS 10 tubes are permitted only as outlet tubes in the radiant section of vacuum heaters. Convection section tubes in steam system service shall not be larger than NPS 4. Convection section tubes in other services should preferably be NPS 6 or smaller in size.
- c. The number of passes shall be minimized. Each pass shall be a single circuit from the inlet to the outlet. Each of the passes shall have an identical number of tubes and fittings.
- d. Minimum process fluid mass velocity for reboiler services shall be 200 lb/sec-ft² (980 kg/sec-m²).
- e. In-tube linear velocity at flowing conditions in an all liquid region shall be 3 feet per second (1.0 meter per second) to 12 feet per second (3.6 meter per second).
- f. Evaluation of the maximum tube metal temperature in the radiant section shall be based on clean conditions unless a fouling factor or coking allowance is specified in the UOP Project Specification.
- g. Inside fouling factor for convection section coils shall be as follows:

Service	Inside Fouling Factor	
	h-ft ² -°F/Btu	m ² -°C/W
Process	0.005	0.0009
200 psig (14 barg) steam system		
600 psig (41 barg) steam system	0.001	0.0002

- h. Convection section outside [flue gas side] fouling factors shall be at least 0.002 h-ft²-°F/Btu (0.00035 m²-°C/W) and 0.020 h-ft²-°F/Btu (0.00350 m²-°C/W) for fuel gas and fuel oil/combination firing, respectively.



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- i. The design tube metal temperature shall be a minimum of 50°F (30°C) higher than the maximum calculated tube metal temperature.
- j. The design conditions of terminal flanges and manifolds shall be as follows:
 - (1) The design pressure shall be equal to the coil design pressure [elastic for process coils].
 - (2) The design temperature shall be at least 50°F (30°C) above the maximum operating bulk fluid temperature anywhere in the coil. For steam superheating services, the margin shall be at least 100°F (55°C).
 - (3) Design conditions for all flanges [or manifolds] in a given service shall be identical.
- k. Excess air levels for both natural and forced draft burners shall be 15% and 25% when firing fuel gas and fuel oil, respectively.
- l. Burners shall be sized for higher of
 - (1) 120% of the heat release with the heater operating at the design case duty,
 - (2) 100% of the heat release with the heater operating at the normal case duty with one burner off-line. When the normal case duty is not explicitly specified in the UOP Project Specification, use 100% of the heat release requirement for the design case duty.

The required heat release shall be calculated with the air preheat system [if any] on-line.

When flue gas is imported beneath the convection section, the heat release requirement shall be calculated using imported flue gas quantity and temperature based on the source heater [of the imported flue gas] at minimum normal duty. Unless otherwise explicitly specified in the UOP Project Specification, assume that the minimum normal duty of the source heater is 50% of its design duty.

- m. Minimum three burners shall be provided. Burner design heat release shall not exceed that given below.

	Maximum Burner Design Heat Release, 10 ⁶ Btu/h (MW)	
	Fuel Gas	Fuel Oil or Combination
Natural draft	14 (4.1)	10 (2.9)
Forced draft	18 (5.3)	14 (4.1)

- n. Calculation of flue gas acid dew point temperature shall also consider the contribution of sulfur species in any waste gas streams being routed to the firebox for disposal.



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- o. Plug headers and/or rolled fittings shall not be used.
- p. Coil terminal tubes shall be flanged. Flanged heater terminal connections shall be provided with blanked off auxiliary flanged nozzles on the inlet and the outlet of each pass. Auxiliary nozzles shall be sized as follows:

Flanged Terminal Connection Size	Auxiliary Nozzle Size
≤ NPS 4	NPS 2
> NPS 4	NPS 3

Materials of the auxiliary nozzles shall be the same as the materials of the terminal connections.

- q. On multi-pass heaters with flanged terminals, provide a 1 inch (25 mm) ID long welding neck flanged nozzle for a thermowell on the outlet terminal inside the terminal flange on each pass.
- r. On heaters subject to coking or fouling, provide a 1 inch (25 mm) ID long welding neck flanged nozzle for a thermowell in the crossover piping for each pass.
- s. Crossover piping shall be external, welded and insulated. Pocketed crossover piping shall be provided with flanged drain connections, including blind flanges. The material specification shall be the same as the crossover piping.
- t. Heaters subject to coking or fouling shall be provided with appropriate connections and layout clearances for insertion and removal of mechanical tube cleaning devices ["pigs"].
- u. Floor fired heaters shall be elevated to provide a minimum clearance of 7 feet (2100 mm) between the finished grade and the lowest horizontal structural member or 6 feet 6 inches (2000 mm) between the finished grade and the bottom of the burner plenum, whichever is higher. Other heater styles shall have a minimum clearance of 2 feet 6 inches (750 mm) between the finished grade and the bottom of the floor plate.



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4. EFFICIENCY

- a. Efficiencies shall be based on a minimum radiant loss of 2.0% and 2.5% of the total heat release for heaters without and with combustion air preheat, respectively.
- b. For radiant-convective heaters without flue gas/combustion air preheat, the flue gas temperature leaving the convection section shall be as follows:

Convection Section	Maximum Cold End Approach, °F (°C)
With extended surface	75 (42)
Without extended surface [i.e. all bare tubes]	250 (140)

Notwithstanding the above criteria, the flue gas temperature shall be at least 75°F (42°C) above the calculated acid dew point temperature.

- c. For radiant-convective heaters with flue gas/combustion air preheat, the flue gas temperature leaving the convection section shall be as follows:

Cold End Inlet Temperature [t_{in}], °F (°C)	Maximum Cold End Approach, °F (°C)
$t_{in} \leq 500$ (260)	150 (84)
$t_{in} > 575$ (302)	75 (42)

For intermediate cold end inlet temperatures, the maximum cold end approach may be linearly interpolated.

Further, flue gas temperature leaving the flue gas/combustion air preheater shall be 75°F (42°C) above the calculated acid dew point temperature.

5. RADIANT SECTION

5.1 General

- a. Radiant surface area for heat transfer shall be based on the exposed outside circumferential surface area of the radiant section tubes and return bends only. Credit shall NOT be taken for the surface area of internal jumpovers and shield section tubes.
- b. For radiant-convective heaters wherein the primary service [defined as that service which flows through the radiant coil] is also located in the convection section, minimum radiant surface area for heat transfer shall be calculated as follows:



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$$\alpha = c_0 + (c_1 \times t_{\text{air}}) + (c_2 \times T_{\text{exit}}) + (c_3 \times t_{\text{air}} \times T_{\text{exit}})$$

$$\gamma = \alpha + (1 - \alpha) \times (1 - \beta)$$

$$\text{Area, ft}^2 \text{ (m}^2\text{)} = \gamma \times Q_{\text{Primary}} / q_{\text{Avg}}$$

Where

t_{air} = Combustion air temperature, °F (°C)

T_{exit} = Flue gas temperature leaving the convection section, °F (°C)

β = Fraction of convection section duty absorbed by the primary service

q_{Avg} = Radiant section allowable average flux rate, Btu/h-ft² (W/m²)

Q_{Primary} = Design total absorbed duty in the heater by the primary service, Btu/h (W)

Correlation Coefficient	t_{air} and T_{exit} in °F	t_{air} and T_{exit} in °C
c_0	5.24×10^{-1}	5.37×10^{-1}
c_1	1.01×10^{-4}	1.78×10^{-4}
c_2	3.16×10^{-4}	5.65×10^{-4}
c_3	-6.37×10^{-8}	-2.06×10^{-7}

Note that $\beta = 0$ and $\gamma = 1$ for an all radiant heater [and also for a radiant-convective heater wherein the primary service is located entirely in the radiant section].

- c. Maximum film and tube metal temperatures in the radiant section shall be determined by following the procedures set forth in ISO 13704 / API 530 [including the calculation of the inside heat transfer coefficient] with a minimum longitudinal variation factor $F_L = 1.5$, tube metal temperature factor $F_T = 1.0$ and negligible convective heat flux [i.e. $q_c = 0$].
- d. The height to width ratio [L/D] of the radiant section shall be as follows:

Design Radiant Absorption [Q_{Rad}], 10 ⁶ Btu/h (MW)	L/D	
	Minimum	Maximum
$Q_{\text{Rad}} < 10$ (2.9)	1.50	2.00
10 (2.9) $\leq Q_{\text{Rad}} < 20$ (5.9)	1.50	2.50
$Q_{\text{Rad}} \geq 20$ (5.9)	1.50	2.75

For vertical cylindrical heaters, L/D shall be the straight tube length exclusive of return bends [coil height for cylindrical heaters with helical coil] divided by the tube circle diameter.

For box heaters, an equivalent L/D shall be determined by dividing the height of the wall bank [straight tube length for box heaters with vertical tubes or arbor coils] by the width of the tube bank.



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- e. Burner spacing factor [burner centerline to centerline distance divided by burner tile outside diameter] shall be a minimum of 1.75 and 2.00 for Standard/Low NO_x and Ultra-Low NO_x burners, respectively. Minimum flange clearance between burners shall be 4 inches (100 mm) and 8 inches (200 mm) for natural and forced draft burners, respectively.

Low NO_x burners are defined as staged fuel gas and staged air burners for fuel gas and fuel oil/combination firing, respectively. Ultra-Low NO_x burners are defined as staged fuel gas with internal flue gas recirculation burners for fuel gas firing.

- f. For floor fired heaters, the flame length at burner design heat release shall be 40% to 70% of the inside firebox height [exposed straight tube length for box heaters with arbor coils]. For the purposes of this calculation:

Burner Type	Specific Flame Length, feet per 10 ⁶ Btu/h (mm/MW)	
	Fuel Gas	Fuel Oil or Combination
Standard	1.5 (1560)	2.0 (2080)
Low NO _x	2.0 (2080)	2.5 (2600)
Ultra-Low NO _x	2.5 (2600)	---

For forced draft Low NO_x/Ultra-Low NO_x burners only, the specific flame length shown above may be reduced by 0.25 feet per 10⁶ Btu/h (260 mm/MW).

- g. The minimum horizontal clearance between the burner centerline and the tube centerline shall be as follows:

Clearance, inches (mm) = Maximum of c_4 and $(c_5 + c_6 \times Q)$

Where

Q = Burner design heat release, 10⁶ Btu/h (MW)

Correlation Coefficient	Fuel Gas		Fuel Oil or Combination	
	Q in 10 ⁶ Btu/h	Q in MW	Q in 10 ⁶ Btu/h	Q in MW
c_4	39	995	51	1300
c_5	21	535	33	840
c_6	3	260	3	260

The calculated clearance shall be rounded up to the nearest multiple of 0.25 inches (5 mm). The clearance shall then be further increased by 6 inches (150 mm) for heaters where cracking of the process occurs and by 12 inches (300 mm) for heaters subject to coking and/or fouling.



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- h. The minimum horizontal clearance between the burner centerline and unshielded refractory shall be as follows:

$$\text{Clearance, inches (mm)} = \text{Maximum of } c_7 \text{ and } (c_8 + c_9 \times Q)$$

Where

Q = Burner design heat release, 10^6 Btu/h (MW)

Correlation Coefficient	Q in 10^6 Btu/h	Q in MW
c_7	33	840
c_8	15	385
c_9	3	260

The calculated clearance shall be rounded up to the nearest multiple of 0.25 inches (5 mm).

- i. For floor fired heaters and Ultra-Low NO_x burners only, the total heat release at burner design conditions shall not exceed 250,000 Btu/h-ft² (790 kW/m²) of the radiant floor area.
- j. When multi-cell heaters with dividing air-cooled center walls [airwall] are used, the airwall shall extend to a minimum height of 70% of the inside firebox height. Minimum casing to casing clearance of the airwall shall be 3 feet (900 mm).
- k. When end wall horizontal firing is explicitly specified in the UOP Project Specification, the following requirements shall apply:
- (1) Minimum adjacent burner centerline to centerline distance in the vertical direction shall be higher of 5 feet (1525 mm) and that determined based on Section 5.1e.
 - (2) Minimum adjacent burner centerline to centerline distance in the horizontal direction shall be higher of 4 feet (1220 mm) and that determined based on Section 5.1e.
 - (3) Minimum clearance between the burner centerline and the tube centerline shall be higher of 5 feet (1525 mm) [6 feet (1830 mm) for fuel oil/combination firing] and that determined based on Section 5.1g.
 - (4) For heaters fired from one end wall only, the minimum inside firebox depth shall be at least 4 feet (1220 mm) greater than the flame length at burner design heat release determined based on Section 5.1f. Inside firebox box depth shall not exceed 24 feet (7300 mm).



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- (5) For heaters fired from both the end walls [opposed firing], the minimum inside firebox depth shall be at least 6 feet (1830 mm) greater than two times the flame length at burner design heat release determined based on Section 5.1f. Inside firebox depth shall not exceed 42 feet (12800 mm).
- (6) Minimum clearance between the top burner centerline and the underside of arch insulation shall be 20 feet (6100 mm).

5.2 Vertical Tube Heaters

- a. For cylindrical heaters, the tube circle diameter shall not exceed 35 feet (10700 mm).
- b. Minimum straight tube length [coil height for cylindrical heaters with helical coil] shall be 20 feet (6100 mm).
- c. For box heaters, the straight tube length shall not exceed 35 feet (10700 mm).
- d. For vertical cylindrical heaters subject to coking and/or fouling, the straight tube length shall not exceed 50 feet (15200 mm). L/D [see Section 5.1d] shall not exceed 2.5.
- e. For box heaters with double-fired tubes, minimum clearance [cold and hot position] between the outside surface of the end tube and the end wall [wall normal to the tube bank/burner row] insulation shall be 1 foot (300 mm).
- f. For top supported tubes, minimum clearance during operation between the top of the radiant floor refractory and the outside surface of the bottom return bend shall be 6 inches (150 mm).
- g. Bottom supported designs are only acceptable in heaters with carbon steel tubes. No part of the bottom return bend shall be buried in the floor refractory.
- h. Minimum clearance during operation between the outside surface of the top return bend and the underside of arch insulation shall be higher of 6 inches (150 mm) and 1.5 times the tube outside diameter.

5.3 Box Heaters with Arbor [Wicket or Inverted "U"] Coils

- a. Bend radius shall be 6 feet (1830 mm) to 7 feet (2135 mm).
- b. Exposed straight tube length [top of the radiant floor refractory to bend weld line] shall be 20 feet (6100 mm) to 35 feet (10700 mm).
- c. Tube centerline to centerline spacing shall be at least two times the tube outside diameter.



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- d. Minimum clearance [cold and hot position] between the outside surface of the end tube and the end wall insulation shall be 1 foot (300 mm).
- e. Minimum clearance between the outside surface of the process manifold and the bottom of floor plate shall be 1 foot (300 mm).
- f. Minimum clearance between the outside surface of the bend and the underside of arch insulation shall be 1 foot (300 mm).
- g. Coil pressure drop shall include coil inlet and exit losses of 0.5 and 1.0 velocity heads, respectively.
- h. Inlet distribution and outlet collection process manifolds shall be of the same size. Minimum manifold size shall be such that the maximum velocity head in the collecting manifold does not exceed 10% of the coil frictional pressure drop [coil pressure drop excluding coil inlet and exit losses per Section 5.3g].
- i. When combustion air preheat is specified, the centerline of the burner row may be offset [if required] from the heater centerline to minimize layout interference of the combustion air distribution duct with the process manifold header boxes. The offset shall be towards the inlet leg of the coil. However, minimum clearance between the burner centerline and the tube centerline shall be 6 feet (1830 mm).

5.4 Box Heaters with "U" Coils

- a. Bend radius shall be 5 feet (1525 mm) to 7 feet (2135 mm).
- b. Tube centerline to centerline spacing shall be at least two times the tube outside diameter.
- c. Minimum clearance [cold and hot position] between the outside surface of the end tube and the end wall insulation shall be 1 foot (300 mm).
- d. Minimum clearance during operation between the top of the radiant floor refractory and the outside surface of the bend shall be 6 inches (150 mm).
- e. Minimum clearance between the top of the radiant roof plate and the outside surface of the process manifold shall be 1 foot (300 mm).
- f. Coil pressure drop shall include coil inlet and exit losses of 0.5 and 1.0 velocity heads, respectively.
- g. Inlet distribution and outlet collection process manifolds shall be of the same size. Minimum manifold size shall be such that the maximum velocity head in the collecting manifold does not exceed 10% of the coil frictional pressure drop [coil pressure drop excluding coil inlet and exit losses per Section 5.4f].



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5.5 Horizontal Tube Heaters

- a. The centerline of the bottom radiant tubes shall be at least 2 feet (600 mm) above the top of the radiant floor refractory.
- b. Return bends shall be located within the firebox. Minimum clearance during operation between the outside surface of the return bend and the end wall insulation shall be higher of 6 inches (150 mm) and 1.5 times the tube outside diameter.

6. FIRING EQUIPMENT

6.1 Burners

- a. Unless otherwise specified, burners shall meet all the requirements of ISO 13705 / API 560 and API RP 535.
- b. Burners shall have noise attenuation and individual plenum box design with damper control of the combustion air.
- c. Burners shall be designed for approximately 20 psig (1.4 barg) fuel gas pressure and 75 to 95 psig (5.2 to 6.5 barg) fuel oil pressure. Burners shall be capable of at least 3:1 turndown. Fuel gas from the fuel gas treatment system shall be supplied at 250°F (120°C).
- d. Burners with different design heat releases but firing the same range of fuels in a given heater [e.g. center and side burners in a double fired vertical tube box heater] shall have equal fuel pressure requirement at their design heat release.
- e. Burners with different design heat releases and/or different available draft [e.g. multi-level, end wall firing] in a given heater shall have equal excess air rates at equal damper settings.
- f. For natural draft burners, at burner design conditions, a minimum of 85% of the available draft [air damper fully open] shall be utilized across the burner.
- g. For forced draft burners, at burner design conditions, air side pressure drop shall be a minimum of 2 inches (50 mm) water column across the burner. Maximum air side pressure drop at burner design conditions shall not exceed 6 inches (150 mm) water column or 9 times the available draft at the burner, whichever is lower.
- h. For both natural and forced draft burners, 75% of the air side pressure drop [air damper fully open] shall be utilized across the burner throat. This requirement does not apply for Ultra-Low NO_x burners.
- i. The minimum tip drilling [excluding ignition ports] shall be 3/32 inch (2.38 mm).



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- j. Gas tips and stabilizer cones shall be 25Cr-20Ni [ASTM A 297 Gr HK] metallurgy.
- k. Individual burner tips and risers shall be removable for maintenance. All threaded burner tip connections shall be coated with a high temperature anti-seize paste.
- l. Fuel gas risers and manifolds shall be Type 316L metallurgy with a minimum thickness of 0.109 inches (2.76 mm).
- m. Rotary air control registers are not acceptable. Burner dampers shall be multi-bladed and opposed. Damper blades shall have seal strip construction to obtain a maximum leakage rate of 3% in the fully closed position when subject to the design air side pressure drop conditions. Damper shafts shall be stainless steel and shall have bearing support with grease fittings.
- n. Burner blocks [tiles] shall have a minimum of 85% alumina content and 3000°F (1650°C) service [continuous use] temperature. Burner blocks based on silica and/or calcium cement bonders shall be pre dried to 500°F (260°C). Chemically bonded tiles do not require drying.
- o. Burner blocks shall be furnished with a tile alignment device to insure proper tile installation. For horizontal firing, burner blocks shall be furnished as an integral tile assembly [defined as burner tile pieces mounted on the burner casing and not on the heater wall]. Vendor shall provide procedures and tolerances for burner and burner block installation.
- p. The casing of all burner equipment shall be at least 10 gauge (3 mm) steel.
- q. Each burner shall be supplied with a pressure tap [NPT ½ coupling with stainless steel extension and plug] located in the plenum chamber downstream of the burner damper.
- r. Provide firm seal, pivoting slide plate type sighting and lighting ports [pyrex glass sighting and capped lighting ports for forced draft burners] on each burner. Provide a minimum of one sighting and one lighting port for the pilot. Provide one sighting port for the main gas tip for fuel gas only burners. Provide two sighting ports for the oil tip for fuel oil/combination burners.
- s. Provide 2 inches (50 mm) of lightweight castable refractory on each individual plenum chamber floor for fuel oil/combination burners and/or heaters with combustion air preheat.
- t. For fuel oil/combination burners, the following requirements shall also apply:
 - (1) Individual primary, secondary and tertiary air controls are required.
 - (2) Primary burner blocks shall have a minimum of 90% alumina content. Phosphate bonded blocks are preferred.



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- (3) Oil gun tips shall be 400 series stainless steel. Atomizers and orifice spuds shall be 300 series stainless steel. When the fuel oil contains solid fines, these parts shall be of hardened tool steel.
 - (4) Provide a match mark on the oil gun assembly [oil gun to guide tube base] to allow proper positioning of the oil tip.
 - (5) Provide 100% spare [50% for 12 or more burners] oil gun assemblies, oil gun inserts and storage rack at the heater. Oil guns shall be of the quick detaching type- easily removable during fired heater operation for maintenance.
- u. Witnessed burner testing to define operating range, emissions, stability and flame shape is required for Ultra-Low NO_x burners and strongly recommended for other burner types. Testing protocol shall be in accordance with API RP 535.

6.2 Pilots

- a. Each burner shall be supplied with a gas fueled, inspirating type pilot burner having a flame retention head [John Zink ST-1S or equal]. Inspirator shall be located outside of the burner plenum. Flame retention head shall be 25Cr-20Ni metallurgy.
- b. When specified in the UOP Project Specification, provide an electronic ignition rod suitable for automatic ignition system [John Zink ST-1SE or equivalent]. Automatic ignition system shall be supplied.
- c. Provide a flame rod assembly [Gayesco GFR or equal] for each pilot to supervise the pilot flame only. See Section 6.4a for details.

6.3 Waste Gas Nozzles

- a. When specified in the UOP Project Specification, provide an open-ended nozzle located inside the burner tile to incinerate the specified waste gas stream. Burner vendor shall determine the nozzle size and the number of burners to be equipped with the nozzle.
- b. The waste gas nozzle shall be ASTM A 312 Gr TP310 metallurgy. When the waste gas stream contains more than 25 mol ppm H₂S, the nozzle shall be ASTM A 312 Gr TP321L metallurgy.



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6.4 Flame Detection

- a. Flame rod assemblies shall be in accordance with the following requirements:
 - (1) The flame rod assembly shall be supplied as an integral part of the pilot assembly and shall be designed to allow removal from the pilot without removing the pilot from the burner, shutting off the pilot or shutting off the burner.
 - (2) The flame rod assembly shall contain a replaceable Kanthal A-1 or equal tip with a 3/16 inch (4.76 mm) or greater outside diameter. The flame rod shall be as short as possible with good flame contact under normal pilot firing conditions. The pilot ground area [any material in contact with the flame that will carry current to the ground] shall be a minimum of four times the area of the rod in the flame.
 - (3) The flame rod tip shall be immersed in one of the pilot's stabilization flames rather than fully immersed in the flame in order to extend the working life of the flame rod.
 - (4) Flame rod lead wires shall have insulation rated for 195°F (90°C) or higher. The contractor shall coordinate the design of the burner/flame rod assembly with the burner vendor and the flame rod vendor such that the design of the flame rod insulator is not exceeded during operation.
 - (5) Provide 50% spare tips and one spare flame rod assembly.
 - (6) An ammeter shall be provided in the sensing circuit [locally mounted] to facilitate proper positioning of the sensor. Provide an alarm contact for each sensor which opens on loss of flame. The loss of the pilot flame shall actuate an alarm in the control center. One alarm contact shall be provided for each pilot. Power for the alarm circuit shall be supplied from the control center.
 - (7) Complete wiring diagrams, recommended installation, instruction manual, operational procedures and systematic procedures for checking the system while the heater is in operation shall be furnished. Test kit shall be included.
- b. When specified in the UOP Project Specification, flame scanners shall have dynamic self-checking capability. They shall be provided with a swivel mount [lockable] such that the flame scanning angle can be adjusted. The sighting tube shall be air purged to keep the detector clean, the detector temperature within safe limits, and the sight path free of dirt. The location of the detector shall minimize dirt or moisture obstructions on the sensor lens or sight glass. Flame scanners shall be powered from a reliable power source such as an uninterruptible power supply [UPS].



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7. CONVECTION SECTION

7.1 General

- a. Convection section shall be top mounted with flue gas flowing vertically upwards. Return bends shall be located in header boxes.
- b. Flue gas mass velocity in the convection section shall not exceed 0.40 lb/sec-ft² (2.0 kg/sec-m²) with the heater operating at the design case duty and the air preheat system [if any] on-line.

When flue gas is imported beneath the convection section, the source heater [of the imported flue gas] shall also be at design conditions when evaluating conformance with this mass velocity criterion.

- c. Overhanging convection sections shall not be used. Effective tube length shall not exceed 80 feet (24400 mm). Further, the effective tube length shall be at least 75% [100% for horizontal tube heaters] of the full length convection section.

Heater Style	Full Length Convection Section
Cylindrical	$L = (D^2 - W^2)^{0.5}$
Twin Cylindrical	$L = (D^2 - W^2)^{0.5}$ + c-c distance between the two cells
Other	L = Inside firebox dimension parallel to the convection section

Where

L = Effective tube length of a full length convection section, feet (mm)

D = Firebox diameter [inside insulation], feet (mm)

W = Convection section width [inside insulation], feet (mm)

- d. When intermediate tube sheets are required, convection section width [inside insulation] shall not exceed 12 feet 6 inches (3810 mm).
- e. Except for the first two shield rows, convection section shall be designed with corbels to minimize flue gas bypassing. Corbel height shall be half the transverse pitch.
- f. Minimum clearance between the top of the radiant roof plate and the centerline of bottom convection row shall be 4 feet (1200 mm).

When flue gas is imported beneath the convection section [or radiant to convection flue gas ducts are used], this clearance shall be measured from the top of the flue gas duct [where it enters the convection section] or the top of the convection box floor insulation, whichever is higher.



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- g. Provide cleaning lanes in the convection section. Minimum cleaning lane height [tube centerline to centerline] shall be 2 feet 6 inches (760 mm). Maximum vertical coverage shall not exceed three tube rows [four tube rows up to NPS 4]. Cleaning lanes shall cover all rows, including shield and future rows.

- h. Breeching shall have a minimum clearance beyond the last [present and future] convection row of 3 feet (900 mm).

7.2 Extended Surface

When extended surface elements [fins or studs] are used in the convection section, the following requirements shall apply:

- a. Average heat flux per row on a bare tube basis shall not exceed 20,000 Btu/h-ft² (63100 W/m²).
- b. Serrated [segmented] fins shall not be used. Studs are preferred for severe conditions [defined as fuel oil/combination firing with fuel oil ash content exceeding 0.05 weight percent and/or fuel oil heavier than 10 °API].
- c. Studs shall be cylindrical. Stud row pitch shall be 19.2 planes per foot (63 planes per meter). Studs in alternate planes shall be staggered. Maximum studs per plane shall be as follows:

Nominal Pipe Size	Maximum Studs per Plane
NPS 3	12
NPS 3.5	
NPS 4	14
NPS 5	18
NPS 6	22
NPS 8	28

- d. Fin [or stud] tip-tip clearance shall be at least 1.50 inches (38 mm). For severe conditions per Section 7.2b, this clearance shall be at least 2 inches (50 mm).
- e. Extended surface metallurgy shall be selected in accordance with ISO 13705 / API 560 except that carbon steel shall be limited to 800°F (425°C) and 900°F (480°C) for fins and studs, respectively. Further, 2.25Cr-1Mo or 5Cr-0.5Mo fins or studs shall not be used.
- f. Attachment of extended surface fins to the tube shall be by means of high frequency continuous welding.



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7.3 Sootblowers

Provide fully retractable sootblowers for fuel oil/combination firing. The following requirements shall apply:

- a. Soot blowing shall cover all rows including shield and future rows. The maximum vertical and horizontal coverage from the lance centerline shall not exceed either 3 feet 6 inches (1070 mm) [3 feet (915 mm) for severe conditions per Section 7.2b] or three tube rows [four tube rows up to NPS 4], whichever is less. Tube supports shall be considered as a limit to individual sootblower coverage.
- b. Sootblower system shall be complete including wall boxes, isolation valves, steam valves, steam piping and motor driven elements.
- c. Provide local push button control. For four or more total sootblowers, provide automatic sequential control with provision for remote operation of any sootblower element.
- d. Minimum sootblower lane height [tube centerline to centerline] shall be 2 feet 6 inches (760 mm). Minimum clearances shall be as follows:

From Lance Centerline to	Clearance, inches (mm)
Outside surface of bare tube	7.5 (190)
Stud tip	9.0 (230)
Fin tip	12.0 (305)
Intermediate/end tubesheets	36.0 (915)

Allow appropriate clearance to cover the vertical deflection [droop] of the sootblower lance in traversing the convection section width.

8. FLUE GAS DUCTING

- a. Flue gas velocities in the radiant to convection flue gas ducts [or ductovers for all radiant heaters] shall not exceed 15 feet per second (4.6 meter per second) with the heater operating at the design case duty and the air preheat system [if any] on-line.
- b. Flue gas velocities in the off takes from the breeching to the stack shall not exceed 20 feet per second (6.1 meter per second) at the design case duty. This shall consider that any air preheater present is being bypassed.

This velocity criterion shall also apply to the duct sections [downstream of the convection section] that handle flue gas when any air preheater present is being bypassed.

- c. Minimum dimension [inside insulation] of any flue gas duct shall be 2 feet [610 mm].



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9. STACK

9.1 General

- a. Stack shall be designed so that a minimum draft of 0.10 inch (2.5 mm) water column is maintained in the radiant and convection sections at maximum ambient temperature and 130% of design case heat release with design excess air. This shall consider that any air preheater present is being bypassed. Further, the flue gas temperature profile shall be assumed per the design case.
- b. Stack velocity shall not exceed 20 feet per second (6.1 meter per second) at design case heat release. This shall consider that any air preheater present is being bypassed.
- c. If higher stack exit velocities are required, a reducing cone [removable] with a maximum included angle of 45° shall be provided at the stack exit. Stack height calculations shall consider the effect of the reducing cone on the hydraulic resistance.
- d. When specified in the UOP Project Specification, the stack length [measured from the top of the convection box] is based on draft considerations alone and assumes a furnace mounted stack.
- e. The top of the stack shall be at least 15 feet (4500 mm) above the top of the highest platform within a 100 feet (30000 mm) radius. Further, the stack height shall be sufficient to meet all safety and local pollution control requirements.
- f. When multiple flue gas off takes from the breeching to the stack are used, the off takes shall enter the stack at a 45° angle. Provide a vertical partition plate extending across the stack diameter from the bottom of the off take tie-in to a height of 0.5 times the stack diameter above the top of the off take tie-in to the stack.
- g. When specified in the UOP Project Specification, provide a stub stack for regeneration purposes. Stub stack shall have a minimum height of 10 feet (3000 mm) above the ductwork and a minimum diameter [inside refractory] of 3 feet (900 mm). Stub stack shall be provided with an internally insulated, removable, bolted and gasketed stack cover. Stack cover shall be removed only during regeneration.
- h. Provide a 300 series stainless steel stack damper [including shaft] equipped with a position indicator that is visible at the control device and a manually operated two-way control device accessible from grade.
- i. Stack damper shall be multi-bladed, opposed motion louver-type. Damper shall fail locked open on loss of signal.



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- j. Dampers for draft control shall be located such that there exists at least one hydraulic diameter straight run of duct [without any flow path obstruction like that of the partition plate in Section 9.1f, axis and/or cross-sectional changes, duct tie-ins etc.] immediately upstream/downstream of the leading/trailing edge of the damper blades in the fully open position.

9.2 Dampers

- a. Dampers shall be furnished by a specialty damper company.
- b. Damper frames shall be strong enough to permit installation handling without special bracing and rigid enough to resist transmitted duct dead weight loads without interfering with operation. Damper internals shall block no more than 25% of the duct area.
- c. All damper operating components shall be replaceable without removing the damper frame from the duct.
- d. Shafts shall be corrosion resistant material capable of transmitting full operating torque without exceeding 33% of the shear yield stress and operator stall torque without exceeding 45% of the shear yield stress. Internal shaft connections shall be stronger than external connections.
- e. Damper shafts shall be mounted in self-aligning, heavy duty, non-lubricated sleeve bearings located in external blocks. Bearings shall be protected from the flue gas by a gas-tight packing.
- f. Linkages shall have minimum clearance, corrosion resistant pivots. Linkages shall not have cumulative clearances [backlash]. The linkage shall be capable of transmitting the operator stall torque. The linkage shall be adjustable to permit field alignment.
- g. Damper blades shall have a centered axis of rotation.
- h. The damper or guide vane mechanism shall be inter-connected to a single operator. The operating mechanism shall be designed so the damper or guide vanes can be manually secured in any position. Damper shall be equipped with a position indicator.
- i. Damper actuators may be pneumatic, electric, or hydraulic. Damper actuators shall be sized to account for duct deposits, dirt loads, and thermal distortions. Damper actuators shall be capable of delivering 150% of the maximum required operating force with the minimum available air pressure. Damper shafts and linkages shall be capable of handling operator forces 150% greater than that produced by the maximum air pressure.
- j. For all pneumatic damper operators, provide an I/P transducer [4-20 mA in, 3-15 psig (0.2-1.0 kg/cm²) out].



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- k. For all double acting piston actuators, provide a volume tank with the required accessories to move the control valve to the minimum signal position as specified, upon loss of instrument air pressure.

10. INSTRUMENT CONNECTIONS

10.1 Oxygen/Combustibles Analyzer

- a. Provide a 3.75 inch (95 mm) hole with mounting bracket for a combination oxygen/combustibles analyzer connection. Contractor shall confirm that the connection size matches the analyzer purchased.
- b. The following requirements shall apply:
 - (1) The connection shall be located immediately above the radiant section [one per cell unless Section 10.1b(5) applies].
 - (2) The connection shall be centered along the major dimension of the flue gas duct leaving the radiant section.
 - (3) When multiple flue gas ducts leaving the radiant section are used [e.g. double fired, "U" coil heater], the connection shall be located in the main flue gas duct of each cell.
 - (4) When flue gas is imported beneath the convection section of a radiant-convective heater, the connection shall be located prior to the measurement being influenced by the imported flue gas.
 - (5) When Ultra-Low NO_x burners are used, provide at least two connections per radiant cell. Locate at approximately 25% and 75% along the major dimension of the duct.

10.2 Flue Gas Temperature

- a. Provide NPT 1 coupling with stainless steel sleeve and plug for flue gas thermocouple connection.
- b. When floor fired Ultra-Low NO_x burners are used, provide at least two connections in the radiant floor per radiant cell. Connections shall be distributed over the radiant floor area.
- c. Bridgwall temperature- The following requirements shall apply:
 - (1) The connection shall be located immediately above the radiant section [one per cell unless Section 10.2c(3) applies].
 - (2) The connection shall be centered along the major dimension of the flue gas duct leaving the radiant section.



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- (3) When multiple flue gas ducts leaving the radiant section are used, provide one connection in each duct.
- (4) When flue gas is imported beneath the convection section of a radiant-convective heater, the connection shall be located prior to the measurement being influenced by the imported flue gas.
- d. For multi-cell heaters or multiple heaters with a common convection section, provide one connection for each 24 feet (7300 mm) of the convection section effective tube length [minimum two]. Locate the connections approximately 1 foot (300 mm) below the centerline of the bottom convection row.
- e. When multiple services are located in the convection section, provide one connection for each 24 feet (7300 mm) of the convection section effective tube length. Locate the connections between services.
- f. When multiple flue gas off takes from the breeching to the stack are used, provide one connection per off take.
- g. For heaters without flue gas/combustion air preheat, provide one connection in the stack below the damper.
- h. For heaters with flue gas/combustion air preheat, provide two connections in the stack. Locate the first connection below the hot flue gas duct to the air preheat system. Locate the second connection above the cold flue gas return duct from the air preheat system.

10.3 Flue Gas Pressure

- a. Provide NPT 1 coupling with stainless steel sleeve and plug for flue gas draft gauge connection.
- b. Provide one connection at the burner level per radiant cell.
- c. Provide one connection immediately above the radiant section [one per cell] and centered along the major dimension of the flue gas duct leaving the radiant section.
- d. Provide one pressure tap connection [for PT or PIC instrument controlling the damper position] approximately 1 foot (300 mm) below the centerline of the bottom convection row and centered along the convection section length.
- e. When multiple flue gas off takes from the breeching to the stack are used, provide one connection per off take.
- f. Provide two connections in the stack located upstream and downstream of the stack damper. For heaters with flue gas/combustion air preheat, the connections shall be located below the hot flue gas duct to the air preheat system and above the cold flue gas return duct from the air preheat system.



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10.4 Flue Gas Sampling

- a. Provide NPT 1 coupling with stainless steel sleeve and plug for flue gas sampling connection [for use with a portable combustion analyzer].
- b. Connections shall be in accordance with Sections 10.2c through 10.2h.
- c. The contractor shall coordinate with the heater vendor and specify any additional connections required [e.g. stack SO_x, NO_x, opacity etc.] to meet owner standards and/or applicable governmental or local requirements.

10.5 Tube Skin Thermocouples

When tube skin thermocouples [TXE] are specified in the UOP Project Specification, the following requirements shall apply:

- a. Locate the thermocouples facing the burners at an elevation coincident with the anticipated hot spot location [for floor fired heaters, approximately 33 to 50% of the flame length above the top of the radiant floor refractory].
- b. One thermocouple shall be placed on each radiant pass outlet tube. Remaining thermocouples for each pass shall be distributed over the other tubes so as to minimize the distance between the TXE's and the burners.
- c. For vertical tubes with two phase flow, the thermocouples shall be distributed as evenly as feasible between tubes with up and down flow direction.
- d. The thermocouple vendor and the contractor shall determine the optimum thermocouple exit locations from the firebox. Thermocouple shall be routed to avoid high radiant heat load. Thermocouple leads shall be sized for thermal expansion of the heater tubes.
- e. A shielded thermocouple design is required. Radiation impingement shield shall have factory installed insulation molded to ensure proper placement of shield.
- f. A retractable thermocouple design [Gayesco Xtracto-Pad or equal] is recommended for ease of maintenance. The retractable thermocouple design shall have the following features:
 - (1) Welding of attachment hardware shall occur only during initial installation.
 - (2) Replacement of thermocouple shall not require welding.
 - (3) Compression fitting shall be stainless steel.



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- g. Each tube skin thermocouple assembly shall consist of a magnesium oxide insulated, metal sheathed thermocouple element complete with stainless steel connection head. The thermocouple element shall be Type K [Chromel-Alumel]. The sheath shall be 73Ni-24Cr-1.4Si alloy material. Sheath, after installation, shall be insulated with either ceramic fiber cloth or moldable ceramic fiber.
- h. The formed section of the attachment apparatus shall be formed to the outside diameter of the heater tube. The contractor shall coordinate with the thermocouple vendor to determine the design and dimensions of the sensor assembly based on the heater vendor's certified prints.
- i. The thermocouple vendor shall determine the metallurgy and spacing of the routing clips [maximum 18 inches (450 mm) apart] and shall furnish the installation drawings. The heater vendor shall determine the weld details with assistance from the thermocouple vendor.
- j. The temperature readout device shall be suitable for use with grounded junction thermocouples.
- k. The thermocouple vendor's design together with the attachment procedure shall produce a measurement accuracy within 20°F (11°C) of the actual surface temperature. The vendor shall furnish a single point calibration for each element at the maximum calculated [clean conditions] tube metal temperature.

11. COIL SPECIFICATIONS

- a. Tube wall thickness for process coils shall be determined in accordance with ISO 13704 / API 530 with corrosion fraction $f = 1.0$. Tube thickness shall be at least Schedule 40 average wall.
- b. The thickness of tubes in steam generation, steam superheating and boiler feed water preheating services shall be in accordance with ASME Boiler and Pressure Vessel Code, Section I.
- c. Maximum design temperatures for coils designed in accordance with API 530 shall be as follows:

Material	Maximum Design Temperature, °F (°C)
Carbon steel	800 (425)
1.25Cr-0.5Mo	1000 (540)
2.25Cr-1Mo	1100 (595)
9Cr-1Mo	1175 (635)



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- d. Minimum corrosion allowance shall be as follows:

Material	Corrosion Allowance, inch (mm)
Carbon steel	0.125 (3.2)
1.25Cr-0.5Mo through 9Cr-1Mo	0.080 (2.0)
Austenitic stainless steels	0.063 (1.6)
Alloy 800H	0 (0)

- e. If the wall thickness is specified as “average”, the allowable dimensional tolerance shall be in accordance with ASTM A 530. If “minimum” wall is specified, the permissible variation shall conform to ASTM A 450.

- f. Heater tubes may be supplied either to pipe or tube specification. Coil components shall be in accordance with the following ASTM specifications:

Material	Pipe	Tube	Welding Fittings
Carbon steel	A 106 Gr B	A 192	A 234 Gr WPB or A 105
1.25Cr-0.5Mo through 9Cr-1Mo	A 335	A 213	A 234 or A 182
Austenitic stainless steels	A 376	A 213	A 403 or A 182
Alloy 800H	B 407	B 407 or B 163	B 366 or B 564

- g. When cast fittings are explicitly specified as an acceptable alternate to wrought fittings in the UOP Project Specification, they shall be in accordance with the following ASTM specifications:

Material	Cast Fittings
Carbon steel	A 216 Gr WCB
1.25Cr-0.5Mo through 9Cr-1Mo	A 217
Austenitic stainless steels	A 351

- h. All Type 321H and 347H stainless steel pipe, fittings and flanges shall be in the stabilized heat treated condition. The stabilization heat treatment shall consist of holding the material at 1650°F (900°C) for a minimum of 4 hours. Stabilizing heat treatment of Type 321H/347H stainless steel weldments is recommended.



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- i. When Alloy 800H is used for design temperatures greater than 1000°F (540°C), the following requirements shall apply:
 - (1) [Ti + Al] content shall be less than 0.70%.
 - (2) All welds shall be postweld heat treated [PWHT] per ASME Section VIII, Division 1, Part UNF-56.
- j. When Alloy 800H is used for design temperatures greater than 1400°F (760°C) but less than 1600°F (870°C), the following requirements shall apply:
 - (1) Requirements of Section 11.i.
 - (2) Grain size of the material shall be 2 to 5 [inclusive] per ASTM E 112.
 - (3) Any component cold worked more than 10% shall undergo a post-deformation solution anneal at 2100°F (1149°C) to restore the course grains.
- k. Coils shall be fabricated in accordance with ASME B31.3.
- l. Center welded or butt welded tubes are not permitted unless their length exceeds that which can be produced at the mill. If center welded tubes are used, it shall be so stated explicitly in the supplier's proposal.
- m. Welding shall be done by the electric arc process using electrodes having the same composition as the tubes and fittings. In the case of dissimilar metals, the composition of the welding electrode shall be at least that of the higher alloyed material.
- n. Back-up rings shall not be used in the coil fabrication.
- o. Exemptions from heat treatment are not permitted for chromium-molybdenum welds.
- p. 100% of carbon steel intermediate welds in the convection section [i.e. inside the end tube sheets] shall be 100% radiographed. 10% of all other carbon steel welds [randomly selected] per welder shall be 100% radiographed.
- q. 100% of all other welds [i.e. excluding those that are covered by Section 11.p] shall be 100% radiographed.
- r. When postweld heat treatment is required, the radiographic examination shall be performed upon completion of the heat treatment.



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12. MANIFOLDS

12.1 General

- a. Process and steam system manifolds shall be designed in accordance with ASME B31.3 and ASME Boiler and Pressure Vessel Code Section I, respectively.
- b. Mechanical design conditions shall be per Section 3.j. When the manifold metallurgy is the same as that of the connecting tubes, the corrosion allowance for the manifolds shall match that for the tubes. Otherwise, the minimum corrosion allowance shall be per Section 11.d.

12.2 Radiant Process Manifolds

When process coil distribution and/or collection manifolds are used, the following requirements shall apply:

- a. Coil shall be attached to the manifold with weldolet fittings or an extruded header may be used. Extended weldolet fittings are preferred over standard weldolets to place the tube butt weld outside the heat affected zone.
- b. Longitudinal seams on the manifold shall not be in the manifold support or tube attachment area.
- c. When welding manifold sections, the longitudinal seams shall be offset from each other.
- d. Manifolds shall be located in removable header boxes. Header boxes shall be internally lined with 4 inches (100 mm) minimum thickness calcium silicate block insulation [temperature class 950°C] or 6 lb/ft³ (96 kg/m³) density ceramic fiber blanket insulation suitable for 1800°F (982°C). Minimum clearance between the manifold outside surface and the lining shall be 4 inches (100 mm).
- e. Header boxes shall be shielded from the radiant section with woven ceramic fiber fabric tube seals, 3M Nextel Style AF-30 or equal, filled with loose ceramic fiber. Radiation shield plates are an acceptable substitution for Nextel seals. Shield plates shall be ASTM A 351 Gr HK40, insulated on the cold side [hot side for bottom manifolds]. Shield plates shall not be attached to the tubes and shall permit free movement of the tubes. Seals or shield plates shall be capable of accommodating 150% of all anticipated piping movements.
- f. Manifolds shall be constant spring supported or counterweighted to allow for thermal expansion of the transfer piping. Top manifolds shall be constant spring supported. Contractor shall determine the final design header movements and the heater vendor shall provide for at least 120% of the calculated imposed header movements in the heater and the support. Fixed terminals are not permitted.



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- g. Type 347 manifolds shall be constant spring supported. Attachment to the manifold shall be cradle type with sling or multiple U-bolt type support. When the pipe diameter exceeds 16 inches (406.4 mm), Type 347 manifolds in accordance with ASTM A 358 Gr TP347 Class 1 with 0.04 weight% minimum carbon content may be substituted.
- h. When manifold plug fittings are specified, spring supports and structure shall be designed for operation with the manifold plug fitting.
- i. Provide ceramic fiber cloth seals for manifold support penetrations through the header box. Provide a weathershield on the support rod to prevent rain ingress.
- j. Process end of the manifold shall be beveled for welding. Provide an eccentric reducer [flat on the bottom], if required, to match with the transfer line size.
- k. Provide a blind flange on the dead end of each manifold. Blind flange shall be located outside the manifold header box.
- l. When outlet manifold plug fittings are NOT specified:
 - (1) If the manifold size exceeds NPS 24, the heater vendor may provide an eccentric reducer [flat on the bottom] with NPS 24 blind flange.
 - (2) Provide a vortex breaker on each blind flange. See Figure 1.
- m. Provide removable weathershield covers for the blind flanges. See Figure 2. Modify the details shown therein as required for use with the blind flanges. Covers shall be installed after final hot bolting.
- n. Provide one NPS 2 drain connection with blankoff on each bottom manifold.

12.3 1.25Cr-0.5Mo Components

When 1.25Cr-0.5Mo components are used for the process manifolds [radiant or convection], the following requirements shall apply:

- a. Pressure retaining components [regardless of size, thickness or product form] shall be postweld heat treated in accordance with the requirements of ASME B31.3. No exemptions from postweld heat treatment are permitted.
- b. The maximum room temperature tensile strength of all pressure retaining components and welds shall be 100,000 psi (7030 kg/cm²).
- c. Fillet welds to pressure retaining components shall be ground to a smooth, concave contour.
- d. Pressure retaining welds, whether shop or field, shall be 100% radiographed. Branch welds that cannot be radiographed shall be 100% ultrasonically examined.



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- e. Accelerated cooling from the austenitizing temperature is acceptable, where permitted by the applicable product form specification.
- f. When the pipe diameter exceeds 16 inches (406.4 mm), A 691 Class 22 may be substituted for A 335 P11.
- g. For design temperature above 825°F (440°C):
 - (1) Charpy V-notch impact testing is required for all pressure retaining longitudinally fusion welded pipe, components and welds. Impact tests shall be conducted in accordance with the requirements of ASME B31.3, except that there shall be no exemptions from impact testing and the test temperature shall be the lower of the design minimum metal temperature and 0°F (-18°C). The test specimens shall be supplied in the same heat treated condition as the new pipe.
 - (2) The product analysis content of tin and phosphorous for pressure retaining components and welding consumables shall be less than 0.015% and 0.012% respectively. The percentage limits are weight percent.

12.4 2.25Cr-1Mo Components

When 2.25Cr-1Mo components are used for the process manifolds [radiant or convection], the following requirements shall apply:

- a. Requirements of Sections 12.3a through 12.3e.
- b. When the pipe diameter exceeds 16 inches (406.4 mm), A 691 Class 22 may be substituted for A 335 P22.
- c. For design temperature above 650°F (345°C) and longitudinally electric fusion welded pipe:
 - (1) Certified chemical analyses including Ni, Cu, As, Sn, and Sb shall be provided for all components.
 - (2) Material shall have a "J" factor defined as $(Si + Mn) \times (P + Sn) \times 10^4$, less than or equal to 100, where the concentrations are in percent. In addition, the nickel [Ni] content shall be equal or less than 0.30% and Copper [Cu] content shall be equal or less than 0.20%. Concentrations are in weight percent.
 - (3) Welding consumables shall be in accordance with the following:
 - (a) Mn and Si levels shall be maintained at the lowest possible levels consistent with good weldability.



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- (b) Each batch or heat of welding consumable and covered electrodes, including the wire flux combinations used in fabrication, shall be analyzed for P, Sn, Sb, and As. Analysis shall be performed on deposited weld metal. The Temper Embrittlement Factor, X-bar, shall be as follows:

$$X\text{-bar} = (10 P + 4 Sn + 5 Sb + As) / 100 \leq 15 \text{ parts per million}$$

Element concentrations are in parts per million

- (4) Charpy V-notch impact testing is required for all pressure retaining longitudinally fusion welded pipe, components and welds. Impact tests shall be in accordance with the requirements of ASME B31.3, except that there shall be no exemptions from impact testing and the test temperature shall be the lower of the design minimum temperature and -20°F (-29°C) and the average impact values of the three specimens shall not be less than 40 ft-lb (55 Joules) with no single value below 35 ft-lb (47 Joules). The test specimens shall be supplied in the same heat treated condition as the new pipe.
- (5) Impact energy versus temperature [transition] curves shall be developed for each heat of plate, pipe and weldments representing each batch or heat of welding consumable, covered electrodes, and wire flux combinations for each welding process used in production welds.
- (a) A minimum of eight sets of three impact tests [of material subjected to the same heat treatment as the completed item] shall be conducted for each curve. Sample locations shall be as specified in ASME Section VIII, Division 1.
- (b) The eight sets of impact tests shall be performed at different temperatures, but shall include the impact test temperature from Section 12.4c(4). The remaining test temperatures shall be selected so that the generated transition curve shall clearly define the transition zone and upper shelf. The maximum test temperature shall correspond to the upper shelf energy level.
- (6) The impact tests shall be performed at different temperatures, but shall include the impact test temperature specified for the piping and -20°F (-29°C). The remaining test temperatures shall be selected so that the generated transition curve clearly defines the transition zone and the upper and lower shelf. The maximum test temperature shall be on the upper shelf energy level [defined as 100% shear fracture] and the minimum test temperature shall be on the lower shelf energy level [defined as zero percent shear fracture]. The upper and lower shelves shall each be defined by at least two test points, with at least four additional points defining the transition curve.



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- (7) Step Cool Tests shall be performed on a sample [subjected to the same heat treatment as the completed item] from each heat of plate, pipe and weldments representing each batch or heat of welding consumable, covered electrodes, and wire flux combinations for each welding process used in production welds.

- (a) Step cooling shall be in accordance with the following temperatures, holding times, and cooling rates to the next lowest temperature.

Temperature, °F (°C)	Holding Time, Hour	Cooling Rate to the Next Temperature, °F (°C) per Hour
1100 (595)	1	10 (6)
1000 (535)	15	10 (6)
975 (525)	24	10 (6)
925 (495)	60	5 (3)
875 (470)	100	50 (28)
600 (315)		air cool

- (b) Impact tests of each Step Cool Test sample shall be performed and transition curves developed per the requirements of Section 12.4c(5).
- (c) Acceptance criteria for the material shall be in accordance with the following:

$$CvTr40 + 2.5 \Delta CvTr40_{sc} < 50^{\circ}F (10^{\circ}C)$$

Where

$CvTr40$ = Charpy V-notch 40 ft-lb (55 Joules) impact energy transition temperature of completely heat treated specimens before step cooling

$\Delta CvTr40_{sc}$ = The shift in the Charpy V-notch 40 ft-lb (55 Joules) impact energy transition temperature after step cooling

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13. FLANGES & GASKETS

- a. Flanges shall be raised face welding-neck [RFWN]. Further, the flanges shall be ASME Class 300 as a minimum.
- b. Flange classes are specified in accordance with ASME B16.5 or ASME B16.47 Series B. Flange classes listed in the UOP Project Specifications are based upon design pressure and temperature conditions only and do not account for other loads. The final design of all flanges shall account for gasket seating and external loads. Differential thermal expansion, including joints between dissimilar materials, and transient thermal conditions such as start-up/shutdown and operational upset shall be accommodated.
- c. Flanges intended for use with spiral wound gaskets shall have a flange surface finish of 125 microinch Ra minimum to 250 microinch Ra maximum. Flanges intended for use with other gaskets shall have a flange surface finish within the optimal range for the specified gasket. Finishes shall be judged by visual comparison with surface finish standards in accordance with ASME B46.1. Flange finishes shall be protected from damage during fabrication, heat treatment, shipping, storage, and installation.
- d. Ring joint flanges shall have a flat bottom groove with the intersection between the bottom and the sides of the groove machined to a smooth 1/8 inch (3 mm) minimum radius.
- e. Flanges and bolts shall be analyzed to ensure that they are not overstressed during gasket seating. Overstressing is more likely to occur when Class 300 and lower flanges are used with spiral wound metal gaskets.
- f. Gaskets for raised face flanges shall be spiral wound in accordance with ASME B16.20, with a non-asbestos filler material. The winding material shall be a minimum of ASTM A 240 Type 304. Gaskets shall include an outer retainer ring. The outer retainer ring may be carbon steel, protected against corrosion. Gaskets for ASME Class 900 and greater flanges and flanges over NPS 24 in all flange classes shall have an inner retainer ring of the same material as the windings. The contractor shall verify the adequacy of all gaskets considering potential buckling of the outer or inner retaining ring(s) and the windings.
- g. Gaskets for ring type joint flanges shall be ring type of the compatible material to the flanges in accordance with ASME B16.20.

14. TUBE SUPPORTS

- a. The unsupported length of horizontal tubes in the radiant section shall not exceed 30 times the outside diameter or 15 feet (4500 mm), whichever is lower. The maximum tube overhang beyond the end tube supports shall be 6 times the outside diameter.
- b. Minimum thickness of end tube sheets shall be 1/2 inch (13 mm). Minimum thickness of intermediate tube support [ITS] flanges and web shall be 5/8 inch (16 mm). Convection section lower ITS shall not be bottom supported design.



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c. The design temperature of the tube supports, retainers, guides and intermediate convection section tubesheets exposed to the flue gas shall be based on the maximum calculated temperature of the flue gas in contact with the support plus a minimum of 200°F (110°C).

d. Radiant tube supports, tube guides, and tube retainers shall have a minimum design temperature of 1650°F (900°C).

e. Metallurgy shall be as follows [unless Section 14.g applies]:

Design Temperature [T], °F (°C)	ASTM Specification
$T \geq 1200$ (650)	A 351 Gr HK40
800 (425) $< T < 1200$ (650)	A 297 Gr HF or A 240 Type 304H
$T \leq 800$ (425)	A 216 Gr WCB or A 283 Gr C

f. Bolts fastening tube support castings to structural steel shall be continuously threaded ASTM A 193 Gr B8. Nuts shall be in accordance with ASTM A 194 Gr 8.

g. When fuel oil heavier than 30 °API is fired and/or the total vanadium and sodium content of the fuel oil is greater than 50 ppm, the metallurgy shall be ASTM A 560 Gr 50Cr-50Ni-Cb for design temperatures greater than 1100°F (595°C). Bolts and nuts for fastening tube support castings shall be of the same material.

h. Inspection of castings shall conform to ASTM E 446. Severity Level 3 shall apply in all categories except critical and flange areas. Critical areas [support areas, bottom flanges, etc.] shall conform to Severity Level 2.

i. Vertical Tube Heaters:

- (1) Top supported tubes shall be provided with bottom guides. Intermediate guides are not required. Radiant top supports for vertical cylindrical heaters shall be "J" hook type. Each radiant bottom return bend shall have one tube guide with Type 310 stainless steel pin and Type 304 stainless steel socket with carbon steel pipe cap cover on the socket.
- (2) Bottom supported tubes shall be provided with guides at the top. Each tube shall have a top guide that is not more than 1 foot (300 mm) below the joint between the tube and the return bend. Spacing of intermediate guides shall not exceed 20 feet (6000 mm).

j. Support castings for wall and hip tubes in a horizontal tube heater processing mixed phase material shall be provided with tube retainers.



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- k. For "U" coils, provide tube spacers at the bottom of the bend [hoop] and on the inlet and outlet legs approximately 4 feet (1200 mm) above the centerline of the top tier of burners. Minimum design temperature shall be 1830°F (1000°C). For fuel gas only firing, tube spacers shall either be ASTM A 351 Gr HK40 or wrought 21Cr-11Ni-N [ASTM A 240 UNS Designation S30815]. For fuel oil/combination firing, the metallurgy shall be ASTM A 560 Gr 50Cr-50Ni-Cb.
- l. For arbor coils, provide two levels of tube spacers on the inlet and outlet legs. The top level of spacers shall be located approximately 6 inches (150 mm) below the joint between the straight tube and the bend. The lower level of spacers shall be located at approximately 50% of the exposed straight tube length. Metallurgy and design temperature shall be in accordance with Section 14.k.

15. REFRACTORIES

15.1 General

- a. Continuous use temperature is defined as the temperature at which the refractory does not suffer any degradation over an extended period of time. The term used for this temperature varies between refractory manufacturers and for the purpose of this standard generally includes other terms such as Recommended Use Limit Temperature and Maximum Service Temperature as it applies to castables, bricks and mortar.
- b. Rated temperature is defined as the temperature which a refractory product is capable of handling without degradation for short periods of time. Rated temperature is most often used in reference to fiber, paper and vacuum formed materials and is significantly below the product melting point. Rated temperature shall not be used as the continuous use temperature.
- c. When specified, dividing brickwalls [gravity walls] between multi-cell heaters shall meet the following requirements:
 - (1) Dividing brickwalls shall be constructed of high-duty, regular type fireclay brick per ASTM C 27. Minimum continuous use temperature of the bricks shall be 2800°F (1538°C).
 - (2) Bricks shall be laid by the rub and tap method to ensure close fitting joints. All the joints shall be as thin as possible.
 - (3) Expansion joints shall not be more than 6 feet (1830 mm) apart. Expansion joints shall be at least 3/4 inch (19 mm) wide.
 - (4) The dividing brickwall shall consist of 4 sections with the following dimensions:

Height:	3 x 5 feet (1525 mm) + 1 x 3 feet 9 inches (1143 mm)
Width:	22.5 inches [bottom] / 18.0 inches / 13.5 inches / 9.0 inches 572 mm [bottom] / 457 mm / 343 mm / 229 mm [top]



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- d. Provide a reed wall when floor fired box heaters with arbor coils are used. The following requirements shall apply:
- (1) Requirement of Section 15.1c(1).
 - (2) Open area shall be in the range of 25-33%. Approximate height shall be 1 foot 0-1/2 inches (318 mm).
 - (3) Reed wall shall be located on either side of the burner row and approximately 1/3 of the distance between the burner centerline and the tube centerline.
- e. Heat loss and cold face temperature calculations shall be based on a surface emissivity value of 0.90.
- f. Any layer of refractory [and anchor metallurgy] shall be suitable for a minimum continuous use temperature [see Section 15.1a] of at least 300°F (165°C) above its calculated hot face [anchor tip] temperature. Minimum continuous use temperature for refractories in the radiant and shield sections shall be 1800°F (980°C).
- g. Minimum design hot face temperatures shall be as follows:

Location	Minimum Design Hot face Temperature
Radiant floor	Bridgewall – 200°F (110°C)
Shielded walls	Average of bridgewall and design tube metal temperature + 100°F (55°C)
Exposed walls, arch, and radiant to convection flue gas ducts	Bridgewall
Convection bare tube section	Higher of (1) Section inlet - 200°F (110°C) (2) Section average flue gas temperature
Convection extended surface tube section	
Breeching	Convection exit
Stack	Convection exit [with combustion air preheat, if any, bypassed]



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15.2 Insulating Castable Refractory

- a. Insulating castables shall be used [i.e. ceramic fiber refractory is unacceptable] in the radiant section when one or more of the following conditions are applicable:
 - (1) Fuel oil is heavier than 30 °API,
 - (2) Total vanadium and sodium content of the fuel oil is greater than 50 ppm,
 - (3) Sulfur content of the fuel oil is greater than 0.5 weight percent,
 - (4) Sulfur content of the fuel gas is greater than 700 mol ppm,
 - (5) Flue gas acid dew point temperature is greater than 260°F (127°C),
 - (6) Refractory backed austenitic stainless steel tubes are used.
- b. Only premixed, bagged, commercial refractory products shall be used. Field mixes are unacceptable. ASTM C 401 Class N material may only be used for backup materials.
- c. Low iron content [maximum of 1.0%] materials shall be used when fuel oil heavier than 30 °API is fired and/or the total vanadium and sodium content of the fuel oil is greater than 50 ppm.
- d. Application, cure, and dryout of the castable refractory shall be as specified by the manufacturer. Installation and testing shall meet all the requirements of ISO 13705 / API 560 and API RP 936.
- e. Minimum anchor diameter shall be 1/4 inch (6 mm). Austenitic material anchors shall be supplied in the solution annealed condition.
- f. Anchor penetration shall not be less than 75% of the individual layer being anchored for castable thickness greater than 2 inches (50 mm). The anchor tip shall not be closer than 3/4 inch (19 mm) from the hot face.
- g. Anchor spacing shall not exceed 8 inches (200 mm) on a square pattern for arches.
- h. A single monolithic layer of castable is preferred. When dual layers are used, separate anchors for each layer shall be provided.
- i. Refractory for heater floors shall be cast. Refractory for walls and arches shall be applied by gunning.



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- j. Minimum required insulation thicknesses and anchor metallurgy are as follows:

Location	Minimum Thickness, inches (mm) [Note 1]	Anchor Metallurgy & Type [Note 5]
Radiant floor	8 (200) [Note 2]	As required
Shielded walls	6 (150)	Type 310 Vee
Exposed walls, arch, and radiant to convection flue gas ducts	8 (200)	Type 310 Vee
Convection side walls without / with sootblowers	5 (125) / 6 (150) [Note 3]	Type 310 Vee in bare tube section.
Convection end tube sheets	4 (100)	Otherwise, Type 304 Vee.
Breeching without / with downstream flue gas heat recovery	3 (75) / 5 (125)	See Section 15.1f
Flue gas off takes without / with downstream flue gas heat recovery	2 (50) / 5 (125)	
Stack	2 (50) [Note 4]	

- (1) Outside casing temperature specified in ISO 13705 / API 560 may be exceeded.
- (2) For fuel oil/combination firing, provide an additional layer of 2.5 inches (65 mm) thick, high-duty, regular type fireclay brick per ASTM C 27.
- (3) When sootblowers are required, provide erosion protection for the entire height of the convection section using 3 inches (75 mm) thick hot face layer of dense castable with a minimum density of 125 lb/ft³ (2000 kg/m³).
- (4) When downstream flue gas heat recovery is used, the stack section below the cold flue gas return duct shall have 5 inches (125 mm) minimum thickness castable insulation.
- (5) Anchor metallurgy shown is minimum required. Requirements of Section 15.1f also apply.

- k. When applicable, convection box floor shall have minimum 6 inches (150 mm) thickness castable insulation and 0.25 inches (6 mm) minimum casing thickness.

15.3 Ceramic Fiber Refractory

- a. All ceramic fiber shall be needled, high purity material.
- b. Studs and washers that are not shielded by the tubes shall be completely covered with a patch fabricated from 1 inch (25 mm) thick, 8 lb/ft³ (128 kg/m³) density ceramic fiber blanket or with moldable ceramic fiber.

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- c. The interior surface of the heater casing shall be coated with 1/8 inch (3 mm) wet thickness of Mastic High Temperature Grade protective coating [high temperature asphalt based material suitable for 350°F (180°C)].
- d. When the sulfur content of the fuel gas is greater than 100 mol ppm and/or the sulfur content of fuel oil is greater than 0.10 weight percent, provide one layer of 0.002 inch (0.05 mm) thick Type 304 stainless steel foil vapor barrier. The vapor barrier shall be located 2 inches (50 mm) from the heater casing between layers of ceramic fiber blankets. Foil edges shall be overlapped at least 8 inches (200 mm). Foil edges and punctures shall be sealed with viscous ceramic fiber refractory cement suitable for 1000°F (540°C).
- e. Minimum required insulation thickness and construction details for layered ceramic fiber blanket installation are as follows:
 - (1) Shielded walls:
4 inches (100 mm) total thickness with Type 310 studs and washers. 2 x 1 inch (25 mm), 8 lb/ft³ (128 kg/m³) density, rated for 2300°F (1260°C) followed by 2 inches (50 mm), 6 lb/ft³ (96 kg/m³) density, rated for 1600°F (870°C)
 - (2) Exposed walls and arch:
6 inches (150 mm) total thickness with Inconel 601 studs and washers. 2 x 1 inch (25 mm), 8 lb/ft³ (128 kg/m³) density, rated for 2300°F (1260°C) followed by 4 inches (100 mm), 6 lb/ft³ (96 kg/m³) density, rated for 1600°F (870°C)
 - (3) Radiant to convection flue gas ducts:
Per Section 15.3e(2) except that the hot face layer [1 inch (25 mm)] shall be wet blanket which air dries to a hard, rigid surface [Thermal Ceramics Cerafiber Wet Pack or equal]
 - (4) Firewalls:
8 inches (200 mm) total thickness with Inconel 601 studs and washers. 2 x 1 inch (25 mm), 8 lb/ft³ (128 kg/m³) density, rated for 2600°F (1427°C) backed with 2 x 1 inch (25 mm), 8 lb/ft³ (128 kg/m³) density, rated for 2300°F (1260°C) followed by 4 inches (100 mm), 6 lb/ft³ (96 kg/m³) density, rated for 1600°F (870°C)

For end wall horizontal firing, the firewalls shall extend to a height of 4 feet (1200 mm) above the centerline of the top level of burners.

For floor fired heaters with exposed walls, the firewalls shall extend to a height of 4 feet (1200 mm) above the flame length determined per Section 5.1f.



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- f. Ceramic fiber modular construction is an acceptable substitution for layered construction. When used, the module design shall be compatible with the mastic coatings and foil vapor barriers [Sections 15.3c and 15.3d]. Ceramic fiber blanket used for module construction shall be at least 8 lb/ft³ (128 kg/m³) density and rated for 2300°F (1260°C). Anchors shall be attached to the casing before the modules are installed.

16. ACCESS & OBSERVATION OPENINGS

16.1 General

- a. Specified sizes below are minimum required clear openings.
- b. For multi-cell heaters, the specified number of openings and doors are for each cell.
- c. Radiant wall observation openings shall meet the following requirements:
 - (1) Openings shall be 6 inches wide x 8 inches high (150 mm x 200 mm). The centerline of the openings shall not be more than 5 feet (1525 mm) above the top of the platform.
 - (2) Openings shall be beveled out [wider opening on the inside] on all the four sides through the radiant wall insulation. An insert constructed from hardened moldable ceramic fiber is preferred.
 - (3) Openings shall be located on the walls such that all the burners and tube surfaces facing the burners can be viewed. Openings shall be centered between the tubes immediately adjacent to the opening.
 - (4) Access to the openings shall not be hindered by piping, instrument connections etc. Further, the opening cover shall be capable of being fully opened without any interference
 - (5) When closed, air infiltration through the doors shall be negligible.
- d. Radiant floor observation openings [to monitor tube and flame interaction at the burner level] for floor fired heaters shall be 4 inches (100 mm) diameter. Provide firm seal, counterweighted, self-closing swing covers. Provide a chain to open the cover.
- e. Access doors shall be bolted and gasketed. Unless otherwise specified, size shall be 2 feet x 2 feet (610 mm x 610 mm). Provide access doors as follows:
 - (1) Radiant section- See Sections 16.2 through 16.4 for location and number of doors. Size shall be 3 feet x 3 feet (915 mm x 915 mm).



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- (2) Convection section- Provide one access door for each 30 feet (9100 mm) of the convection section effective tube length. Locate beneath the convection section.
- (3) Breeching- Provide two access doors in the convection box roof [one on each end].
- (4) Stack- Provide one door for access to the stack damper.
- f. Provide at least one tube removal door [bolted and gasketed] in the radiant roof. Size shall be 2 feet x 2 feet (610 mm x 610 mm).
- g. For convection section inside width up to 6 feet (1800 mm), provide one inspection door per bay [defined as the span between adjacent tubesheets] in each cleaning or sootblower lane [see Sections 7.1h and 7.3d]. When the convection section inside width exceeds 6 feet (1800 mm), provide two inspection doors per bay [one in each side wall]. Inspection door(s) shall be 1 foot 6 inches high x 2 feet wide (460 mm x 610 mm).
- h. Provide adequate number of inspection doors in the convection section side wall. Doors shall be located adjacent to an intermediate tube support and shall permit visual inspection of representative length of each tube row. Bolted and gasketed inspection openings may be substituted for the doors.

16.2 Cylindrical Heaters [Including Helical Coil]

- a. Provide radiant wall observation openings as follows:

- (1) Lower level- One per burner to view the burner area.
- (2) Middle level- When the inside firebox height exceeds 30 feet (9100 mm), provide openings located at approximately 50% of the inside firebox height. Number of openings shall be as follows:

Tube Circle Diameter [D], feet (mm)	Minimum No. of Openings
$D \leq 22$ (6700)	4
$D > 22$ (6700)	6

- (3) Upper level- Locate approximately 6 feet (1800 mm) below the bottom of the radiant roof insulation. Number of openings shall be in accordance with Section 16.2a(2).



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- b. Provide radiant floor observation openings as follows:

Tube Circle Diameter [D], feet (mm)	Minimum No. of Openings
$D \leq 14$ (4300)	3
$14 (4300) < D \leq 18$ (5500)	4
$18 (5500) < D \leq 26$ (7900)	6
$D > 26$ (7900)	8

- c. Provide one access door on the radiant floor.

16.3 Box Heaters [Including Arbor and Horizontal Tube]

- a. Provide radiant wall observation openings as follows:

- (1) Side wall- One per burner on each radiant side wall [wall parallel to the burner row] at the lower level to view the burner area. When burners are located adjacent to the side wall [e.g. double fired, vertical tube box heater], the observation openings shall be centered between the burners immediately adjacent to the opening.
- (2) End wall, Lower level- On each radiant end wall, provide openings to view the tube surfaces facing the burners. Elevation shall be consistent with the side wall openings. Openings shall be located near the tube row centerline approximately $\frac{2}{3}$ of the distance between the burner row centerline and the tube row centerline.

	No. of Openings per End Wall
Single fired tubes	2
Double fired tubes with side burners only	
Double fired tubes with center and side burners	4

- (3) End wall, Middle level- When the inside firebox height exceeds 30 feet (9100 mm), provide openings in each radiant end wall. Locate at approximately 50% of the inside firebox height. Number of openings shall be in accordance with Section 16.3a(2).
- (4) End wall, Upper level- Locate approximately 6 feet (1800 mm) below the bottom of the radiant roof insulation. Number of openings shall be in accordance with Section 16.3a(2) except that for box heaters with single fired arbor coils, a single opening located at the center of the bend is acceptable.



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- b. Provide one radiant floor observation opening for each 10 feet (3000 mm) of the inside firebox length parallel to the burner row [minimum three]. Distribute the openings on either side of the burner row [center burner row for double fired tubes].
- c. Provide one access door per burner row in each radiant end wall. When tubes are located adjacent to the end walls, the access doors shall be located in the radiant floor.

16.4 Box Heaters with “U” Coils

- a. Provide radiant wall observation openings as follows:

- (1) Side wall- Provide at least three openings on each radiant side wall. Locate at approximately 25%, 50% and 75% of the inside firebox length. Elevation of the openings shall be consistent with the lowest level of openings in the end wall [see Section 16.4a(2)].

- (2) End wall, Burner area- On each radiant end wall, provide multiple levels of observation openings in the burner area. Number of levels shall be determined as follows:

$$\text{Number of levels} = N / 2$$

Where

N = Number of end wall burner levels [numbered consecutively from the bottom]

The required number of observation opening levels shall be rounded up to the nearest integer. The n^{th} level of observation openings shall be located midway between the centerline elevations of the $(2n-1)$ and $(2n)^{\text{th}}$ burner levels.

At each observation opening level, provide two and four openings for single and double fired tubes, respectively. Openings shall be located near the tube row centerline approximately $2/3$ of the distance between the burner centerline and the tube row centerline.

- (3) End wall, Middle level- When the distance between the top level of the burner area observation openings per Section 16.4a(2) and the upper level of observation openings per Section 16.4a(4) exceeds 20 feet (6100 mm), provide a middle level of openings in each end wall. Locate at approximately 50% of the distance between the two adjacent levels. Number of openings shall be in accordance with Section 16.4a(2).
- (4) End wall, Upper level- Locate approximately 6 feet (1800 mm) below the bottom of the radiant roof insulation. Number of openings shall be in accordance with Section 16.4a(2).



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- b. Provide three access doors in each radiant end wall.

17. PLATFORMS

- a. Platforms shall be a minimum of 3 feet 6 inches (1000 mm) wide.
- b. A stairway from grade shall be provided to access the platform serving the lower level observation openings in the radiant section. When the inside firebox height exceeds 30 feet (9100 mm) and/or radiant top manifolds are used and/or sootblowers are provided, a stairway shall be provided to the radiant roof/sootblower level. Ladders shall be provided to access all other platforms.
- c. Platforms shall be provided as follows:
- (1) A full peripheral platform to access the lower level of observation openings.
 - (2) A continuous peripheral platform providing access to both the ends of the convection section.
 - (3) For access to the soot blowers- platform shall be adequately wide to cover the outboard end of the sootblowers.
 - (4) At damper, inspection door, tube removal door and access door locations [except floor].
 - (5) As needed to access each analyzer and thermocouple.
 - (6) At all other observation openings and instrument connections, intermediate step off platforms are acceptable.



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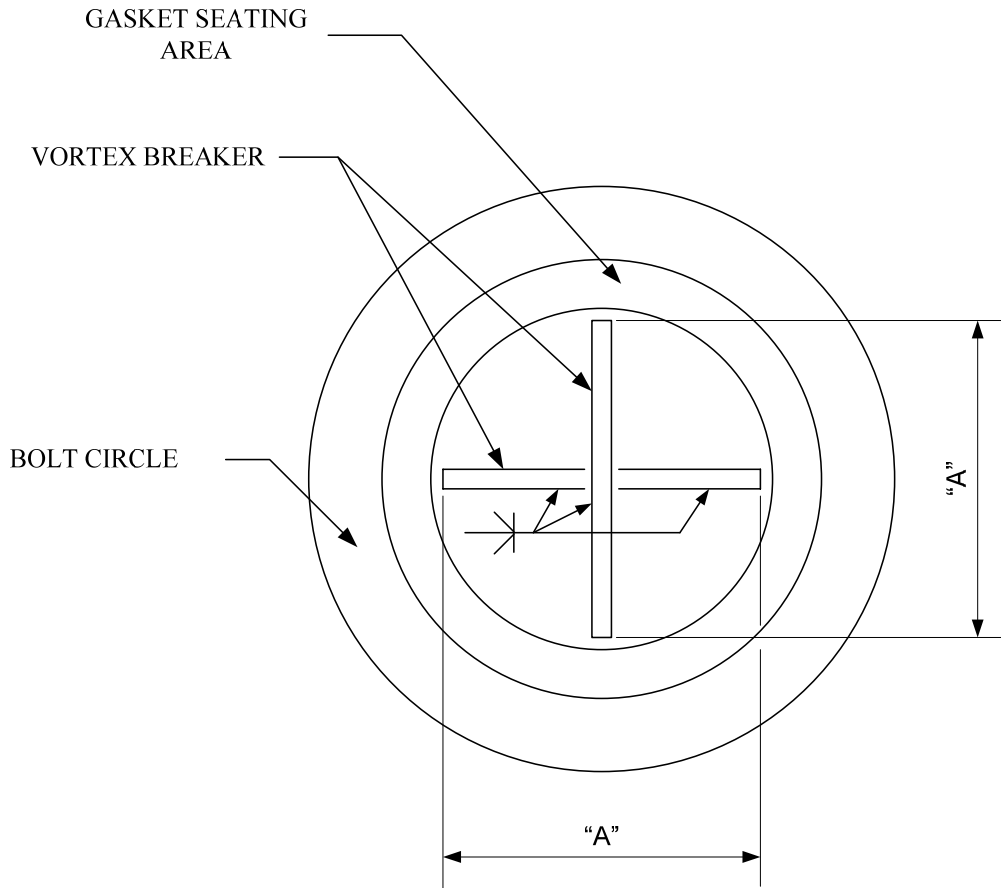
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“A” = MANIFOLD FLANGE ID - 0.50 INCH (12 MM)

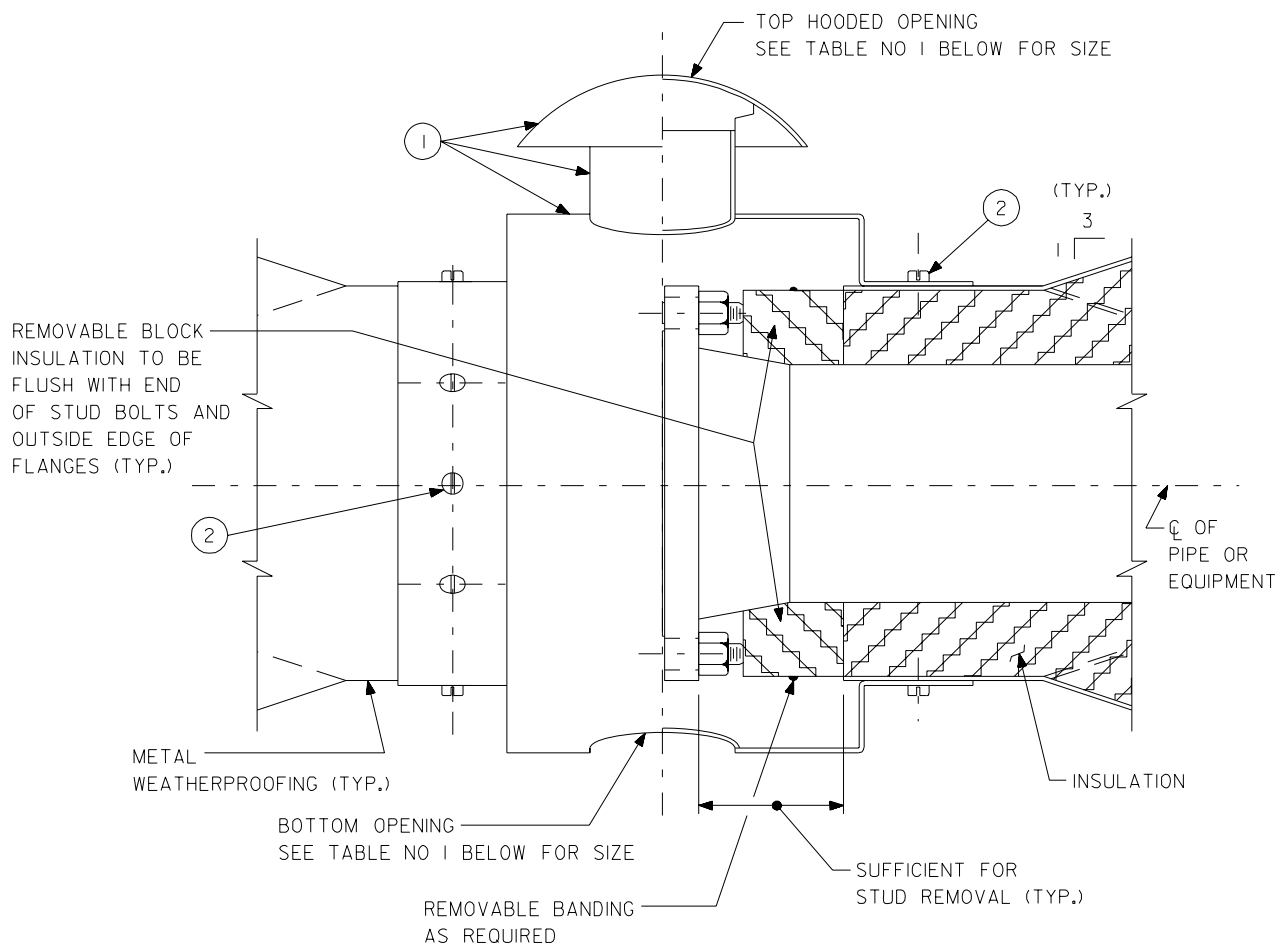
VORTEX BREAKER: 4 INCH (100 MM) HEIGHT x 0.25 INCH (6 MM) THICKNESS PLATE ALLOY MATERIAL TO MATCH FLANGE MATERIAL. MEMBERS APPROXIMATE FLANGE ID (SEE DIMENSION “A”) AND ARE PERPENDICULAR TO EACH OTHER.

BLIND FLANGE SHALL HAVE TWO (2) LIFTING LUGS (NOT SHOWN) TO FACILITATE REMOVAL.

**VORTEX BREAKER IN BLIND FLANGE
FIGURE 1**

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- ① TYPE 304 STAINLESS STEEL.
 ② SELF-TAPPING STAINLESS STEEL SCREWS

TABLE NO 1

Equipment or Line Size		Opening Diameter	
inches	millimeters	inches	millimeters
LESS THAN 6	LESS THAN 150	3	75
6 TO 10	150 TO 250	4	100
12 TO 18	300 TO 450	8	200
20 TO 28	500 TO 700	12	300
30 & LARGER	750 & LARGER	16	400

**REMOVABLE WEATHERSHIELD COVER FOR FLANGES
 FIGURE 2**