

GS 122-1

FIRED HEATERS TO API 560

December 1996

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BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING			
Doc. No. GS 122-1		Issue Date	December 1996
		Latest Amendment Date	
Document Title			
FIRED HEATERS TO API 560 (Replaces BP Engineering Std 162)			
APPLICABILITY			
Regional Applicability:		International	
SCOPE AND PURPOSE			
This Specification covers the general requirements of BP for fired heaters and their associated steel stacks conforming to API Std 560, Fired Heaters for General Refinery Services. This specification provides amplification of existing clauses within API 560, First Edition January 1986 and additional requirements to that standard. Its purpose is to lay down the minimum requirements for design, materials, fabrication, testing, preparation for shipment and erection of fired heaters.			
AMENDMENTS			
Amd.	Date	Page(s)	Description
CUSTODIAN (See Quarterly Status List for Contact)			
BP Oil, Separations and Energy			
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Guidance for Specification

The provision of 'fit for purpose' Fired Heaters and associated equipment which meet the requirements for performance and are of suitable materials of construction and fabrication to allow the required refinery operation.

Application

This Guidance for Specification is intended to guide the purchaser in the use or creation of a fit-for-purpose specification for enquiry or purchasing activity.

It is a transparent supplement to [API Standard 560](#) First Edition, dated January 1986, showing substitutions, qualifications and additions to the API text as necessary. As the titles and numbering of the BP text follow those of API, gaps in the numbering of the BP document may occur. Where clauses are added, the API text numbering has been extended accordingly.

Text in italics is Commentary. Commentary provides background information which supports the requirements of the Specification, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an asterisk (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Specification Ready for Application

A Specification (BP Spec 122-1) is available which may be suitable for enquiry or purchasing without modification. It is derived from this BP Group Guidance for Specification by retaining the technical body unaltered but omitting all commentary, omitting the data page and inserting a modified Foreword.



Principal Changes from Previous Edition

This Guidance for Specification has transpired from the general updating and conversion to the new 'Way Forward' style of BP Engineering Standard 162.

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. GENERAL

1.1 Scope

This Specification covers the general requirements of BP for fired heaters and their associated steel stacks conforming generally to [API 560](#) and where necessary will be used with a supplementary specification to adapt it for a specific application. This specification provides amplification of existing clauses within [API 560](#), First Edition, January 1986 and additional requirements to that standard.

This specification lays down the minimum requirements for design, materials, fabrication, testing, preparation for shipment and erection of fired heaters.

(Substitution for [API 1.1.1](#))

* 1.2 Alternative Designs

This Specification does not cover boilers (other than those integral with the fired heater), dryers or specialised heaters such as field crude heaters and heat transfer fluid heaters. All proposals for the use of specialised heaters shall be subject to approval by BP.

(Substitution for [API 1.1.2](#))

1.6 Referenced Publications

1.6.1 The list of referenced publications shall be replaced by that specified in Appendix Y.

(Substitution for [API 1.6.1](#))

1.7 Proposals

1.7.1 Purchaser's Responsibilities

* 1.7.1.4 A complete list of data and drawings required at each stage of the contract will be specified by BP.

(Addition to [API 1.7.1](#))

Either BP or the purchaser acting on behalf of BP need to specify a drawing production schedule.



1.7.2 Vendor's Responsibilities

4. Vendor's Proposals and Exceptions

The vendor shall state when tendering either that his proposed equipment complies without exception to the requirements of this Specification, or that it complies subject to certain exceptions. A detailed description of any exception together with reasons, cross referenced to the relevant section number of this Specification, shall be given by the vendor.

The vendor may offer alternative proposals which will still meet the intent of this Specification, but such proposals shall form a supplement to the main tender.

(Substitution for [API 1.7.2 item 4.](#))

8. Proposal drawings showing the heater general arrangement, the tube layout, the positions and locations of the ladders, platforms, peepholes, sootblowers, dampers, isolating plates, expansion joints, ductwork, fans, burners and air preheaters.

9. Details of all ancillary equipment, e.g. air preheaters, fans, dampers, sootblowers and burners.

10. Flue gas temperature profiles through the heater at the design conditions.

11. Process fluid pressure, temperature and velocity profiles at the design conditions.

12. Tube thickness/stressing calculations when requested.

13. Details of utility requirements.

14. Details of any instrumentation or control system supplied or proposed by the heater vendor.

15. Design codes proposed for the structural design of the heater(s) and stack(s).

16. Seismic design proposals when requested.

(Additions to [API 1.7.2](#))



1.10 Application of this Specification (Addition to API Section 1)

1.10.1 To apply this BP Specification, supplementary specification and approval actions by BP, purchaser, or both, are required in order to adapt it to each specific project application. These actions, which supplement the checklist in Appendix B of [API 560](#), are indicated by an asterisk (*) preceding a paragraph number.

1.10.2 The titles and numbering of the text of this BP Specification follow those of [API 560](#). As a result of this, gaps in numbering may occur. All text is cross referenced to [API 560](#), and qualifies, substitutes, modifies or adds to the requirements of [API 560](#).

Where additional numbered paragraphs are to be read as an extension of an [API 560](#) section or sub-section, the [API 560](#) text numbering has been extended accordingly.

1.10.3 The order of application of the Specification shall be:-

- (a) Statutory or local regulations.
- (b) Equipment requisition and data sheets.
- (c) BP Specifications
- (d) [API 560](#).

1.11 Co-ordination of Design (Addition to API Section 1)

The fired heater vendor shall co-ordinate the design, and ensure the satisfactory functioning of the complete unit, i.e. heater, air preheater, forced/induced draft fans, drivers, transmissions, and other ancillaries. In cases where the fired heater vendor supplies equipment that he has not manufactured, he shall ensure that the designs of these items are compatible with each other and with his own equipment in all respects, and they shall be included in his guarantee. In particular, they shall be compatible dimensionally, in performance, in control and in vibration such that a fully integrated unit is achieved.

*** 1.12 Quality Assurance (Addition to API Section 1)**

Quality system requirements will be specified by the purchaser.

Verification of the vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core text of this specification. If this is not the case, clauses should be inserted to require the vendor to operate and be prepared to demonstrate the quality system to the purchaser. The quality system should ensure that the technical and QA requirements specified in the enquiry and



purchase documents are applied to all materials, equipment and services provided by sub-contractors and any free issue materials.

Further suggestions may be found in the BP Group RPSEs Introductory Volume.

2. DESIGN CONSIDERATIONS

2.1 Process

- * 2.1.2 The number of passes shall be minimised. Any splitting of passes within a heater shall be subject to approval by BP.

(Substitution for [API 2.1.2](#))

Pass splitting within a fired heater can result in flow mal-distribution and tube burn-out. Pass splitting should be avoided where possible. Where it cannot (occasionally on vacuum heaters and ethylene crackers) the vendor should identify the precautions taken to ensure uniform flow splitting.

- * 2.1.3 The maximum allowable process fluid bulk temperatures, the maximum allowable average heat flux on the radiant section tubes and the minimum mass velocity of the fluid in the tubes (when not specified by BP) shall be subject to approval by BP.

(Addition to [API 2.1.3](#))

Typical allowable flux rates and minimum mass flow velocities for refinery heaters are provided in Table Z. Maximum allowable bulk temperatures are usually a function of the process requirements.

- * 2.1.4 The maximum local heat flux density in the process convection section, excluding those exposed to direct radiation from the radiant section, shall not exceed the maximum local heat flux density elsewhere in the process coil of the heater; both rates referring to the bare external surface of the tubes. Process convection section tubes exposed to direct radiation from the radiant section (shield tubes) shall be spaced at tube centres of not less than those process tubes located in the radiant section.

The vendor shall advise the maximum local heat flux density for each section of all coils (process and utility) together with the local heat flux (circumferential, longitudinal) and metal temperature variation factors as generally described in [API RP 530](#) Appendix C.



The maximum local heat flux density in the process convection section of ethylene, methanol and steam reformer furnaces shall be subject to approval by BP.

(Addition to [API 2.1.4](#))

In cracking and reforming furnaces the maximum allowable flux rates in the radiant (cracking or reforming) sections of a heater are different to those allowable in the convection (the sensible heating) sections. The flux rates in the convection sections are limited by the maximum allowable film temperature (cracking temperature) of the process fluid in order to avoid tube coking.

- * 2.1.5 Where convection sections of a process heater are either wholly or partially utilised to generate steam, then in the case where steam superheater coils are provided, these shall not form part of the first three rows of convection shield sections.

This requirement shall also apply to stripping steam coils located in the convection section of a process heater.

The design of the steam generator shall be subject to approval by BP.

(Addition to [API 2.1](#))

The allowable water-steam circulation rates, the minimum allowable tube side velocities and the maximum allowable heat fluxes for steam generations are a function of steam pressure and water quality.

N.B. It is important that the steam generation operation does not prejudice the process operation and this needs to be taken into account when a steam generation coil is proposed. Problems that can occur include:-

- (a) *The Statutory Authorities requirement for boiler inspections which are more frequent than the heater inspections.*
- (b) *Loss of boiler feed water requiring a heater shut-down.*
- (c) *High superheated steam temperatures requiring either the heater to be shut down or the heater operation limited by the steam temperatures.*

- * 2.1.6 Fired heaters and their auxiliary equipment covered by this BP Specification shall be suitable for all the specified operating conditions, and shall be designed and constructed to operate for at least 4 years uninterrupted continuous service periods between shut-downs, unless otherwise approved by BP.



The design shall take into consideration component design and the selection of materials of construction, to ensure thermal and hydraulic performance is maintained during this period.

(Addition to [API 2.1](#))

Certain units such as vacuum heaters, ethylene crackers and visbreaker heaters have to be shut down at intervals less than 4 years. Where the vendor cannot meet the continuous operation for 4 years requirement, then he should specify:-

- (a) *Why it cannot be met - this could be for process and/or economic reasons. (Frequent heater shut-down requirements are usually caused by tube coking which is a function of flux rates (tube surface areas) and process temperature).*
- (b) *What operating periods can be guaranteed.*

- * 2.1.7 Helical or circular coil configurations shall not be used for two phase flow applications unless otherwise approved by BP.

(Addition to [API 2.1](#))

- * 2.1.8 Unless otherwise approved by BP the design of the fired heater and related equipment shall be such that all metal surfaces in contact with the flue gases shall at all operating loads, including minimum turn down, attain a temperature of at least equal to the recommended minimum metal temperatures given in Fig 4 of [API 533](#).

When required, the vendor shall submit the following data for BP review:-

- (a) Flue gas acid dew point data for the various fuels and/or combination of fuels to be fired.
- (b) The minimum metal temperature calculations for metal parts (in contact with the flue gases) operating at less than 28°C (50°F) above flue gas acid dew point.
- (c) The minimum calculated temperatures for non-metallic parts (in contact with the flue gases) operating at less than 11°C (20°F) above flue gas acid dew point, e.g. air preheater cold end elements, seal packings, duct/stack linings.

Where applicable, account shall be taken of the metallic and non-metallic parts in the header boxes.

(Addition to [API 2.1](#))



2.2 Combustion

2.2.2 In the case of forced draught operation, calculated efficiencies shall be based on at least 15% excess air for both gas and oil fuels. (This assumes 10% excess air at the burners).

(Part-Substitution for [API 2.2.2](#))

* 2.2.4 Combustion air may be supplied by the use of natural draught or fans. In either case, the draught or pressure shall be sufficient to supply to all the burners a combustion air flow 25% greater than that required for operation at the heater design load, with the specified excess air at the maximum ambient air temperature with and without air preheat (where relevant).

In all cases the flue gas system shall be designed so that:-

- (a) anywhere in the combustion chamber (radiant section) the pressure shall be at least 0.25 mbar below atmospheric pressure (minus 0.1 in H₂O),
- (b) anywhere in the ducting and in the stack the pressure shall be at least 0.12 mbar below atmospheric pressure (minus 0.05 in water gauge).

When the flue gas quantity is at least equal to 130% of the heater design load flue gas quantity with design excess air and the flue gas temperature at the fans (if supplied) being at least 15°C (30°F) above the calculated temperature with the furnace on design load. Refer also to section 9.2.

It is preferred that the negative pressure in (a) be maintained without the use of induced-draught (ID) fans but, if they are necessary, then the negative pressure condition in (b) shall still apply.

Unless otherwise approved by BP when the ID fans are fitted then provision shall be made to bypass the induced-draught fans automatically on failure. If ID fans are bypassed, the heater shall still be capable of operating at 70% of its normal load.

The vendor shall submit a combustion air and flue gas mass balance diagram (for BP review) for the complete system together with draught and/or pressure levels at various key locations for the following conditions:-

- (i) At 100% of heater design load and design excess air.



- (ii) At 100% of heater design load and a combustion air flow 25% greater than that required in (i).
- (iii) At the induced-draught fan bypassed condition.

The above conditions shall also include for any air-in leakage requirements specified in section 9.2.1 of this Specification.

(Substitution for [API 2.2.4](#))

On most fired heaters it is easy and relatively cheap to install an induced draught (ID) fan bypass for ID fan failure. Where this is not the case, then consideration should be given to installing two fans (one operating and one stand-by) or two 50% - 60% operating fans.

2.3 Mechanical

- 2.3.1.1 Where steam-air decoking is specified, the coil material together with provisions for thermal expansion shall be suitable for a short term tube metal temperature of at least 675°C (1250°F).

(Addition to [API 2.3.1](#))

This is based on the minimum tempering temperature for 5Cr1/2Mo tube. For 11/4Cr 1/2Mo and carbon steel the respective temperatures are 650°C (1200°F) and 600°C (1110°F) respectively. Note that the tempering temperatures are in excess of the temperature at which scaling will occur and attempts should be made to operate below this temperature whenever possible. The scaling temperatures for 5Cr1/2Mo, 11/4Cr1/2Mo and carbon steel are 650°C (1200°F), 595°C (1100°F) and 565°C (1050°F).

- * 2.3.2 Where extended surface convection banks are installed and the furnace is to be fired on liquid fuels containing residual fractions, sootblowers as specified in 10.2 or some other method of cleaning, approved by BP, shall be fitted. On all other heaters with convection banks, irrespective of the fuel to be fired or whether the convection tubes are plain or have extended surfaces, sootblower lanes shall be provided in the design of the convection banks.

The convection section shall incorporate space for future addition of two rows of tubes.

(Substitution for [API 2.3.2](#))

Other methods of tube cleaning include sonic sootblowers, shot cleaning or off-line water washing.



- 2.3.3 This is superseded by 2.3.2 of this Specification.
- (Substitution for [API 2.3.3](#))
- 2.3.4 The minimum height-to-diameter ratio shall be not less than 1.4. Height-to-diameter ratios of less than 1.4 may only be proposed if the vendor can provide evidence of successful operation of heaters with similar geometry and process conditions.
- (Addition to [API 2.3.4](#))
- 2.3.4. Box or cabin heaters with tubes alongside the walls, shall be designed with a maximum height-to-width ratio of 2.75, where the height is the radiant section height (inside refractory face) and the width is the distance between the centrelines of the two opposite rows of tubes, both measured in consistent units.
- (Addition to [API 2.3.4](#))
- 2.3.6.1 The convection section and flue gas duct work shall be so arranged that even flue gas flow distribution is attained over the entire convection bank and flue gas air preheater, if fitted.
- (Addition to [API 2.3.6](#))
- Corbels are accepted for most fuels; metallic baffles should not be used where the unit is oil fired.*
- N.B. Corbels can be a problem where the convection section is water washed off-line and the refractory has to be protected from the water (i.e. where lightweight insulation is used in the convection section).*
- 2.3.7 Where access for operational reasons is required under a heater, no part of the heater (other than the vertical structural members) including burners, air ducting, plenums, pipework or controls shall be nearer grade than 1900 mm (6 ft 3 in). Burner controls locking devices and other parts under heaters that have to be manually operated from grade shall not be more than 2050 mm (6 ft 9 in) from grade.
- In all other cases, heater floors shall be at least 760 mm (2 ft 6 in) above grade to provide maintenance access. Additionally, the space beneath the floor shall be adequately ventilated so as to limit the flow of heat into the foundations.
- (Substitution for [API 2.3.7](#))



- 2.3.8 No vertical tube length shall exceed 18 m (60 ft) between return bends or return fittings, nor shall its maximum length, without intermediate guides, exceed 80 times the tube OD.

(Part-Substitution for [API 2.3.8](#))

- * 2.3.8.1 Vertical tubes shall be top hung unless otherwise approved by BP. Where vertical 'hairpins' are fitted with guide pins passing through the furnace floor, the ends of the pins shall project through their guide tubes when cold. These pins shall be easily replaceable.

(Addition to [API 2.3.8](#))

Bottom supported tubes are susceptible to tube bowing and bottom supports should only be used where an alternative support system is not possible or when precautions are taken to avoid overloading the tubes (e.g. springs or counterweights at the top of the tubes).

Where bottom supported tubes are proposed the vendor should provide details of how he proposes to avoid tube bowing (buckling).

- 2.3.9 Tubes shall not be located on radiant section floors.

(Addition to [API 2.3.9](#))

- 2.3.11 Coils in heaters on hydrogen service shall be welded throughout. Hydrogen service refers to hydrogen or to mixtures of hydrogen and hydrocarbons in which the partial pressure of hydrogen is 5 bar abs (75 psi abs) or more.

(Addition to [API 2.3](#))

2.4 Noise Control (Addition to API Section 2)

- * 2.4.1 Noise limits for fired heaters and any associated equipment, e.g. fans, will normally be specified in detail in the enquiry. However, in the absence of such requirements noise levels at or beyond 1 m (3 ft) from the heater casing plate (plus ducts, fans and other ancillary equipment) surfaces shall not exceed 85 dB(A).

Noise attenuating enclosures will be accepted only when there is no alternative form of noise control, and their use shall be subject to approval by BP. The design of these enclosures shall be such that the normal operation and maintenance are not unduly compromised. In particular, all instrumentation and controls shall be either mounted externally to the enclosure, or shall be clearly visible and controllable from outside the enclosure.



Enclosures shall be adequately purged and cooled, and their design shall take into account any leakage of hazardous products. Instrumentation, sensors and cables installed inside enclosures shall not be subjected to an environment which causes the components to be operated outside their ambient temperature limits.

Noise attenuating enclosures are enclosures such as walls built around the burners or fans that limit access. It does not mean burner plenums. Enclosures should be avoided on new units.

2.5 Design Codes (Addition to API Section 2)

2.5.1 Pressure Parts

- * 2.5.1.1 Pressure parts that normally operate under negative pressure or with design pressures below 1 bar ga (15 psig), such as vacuum heater tubes or air to flue gas preheaters, shall be designed to the vendor's standard practice; however, the basis for design shall be subject to approval by BP.

Tubes that operate under negative pressure should be designed in accordance with ASME Section VIII when the tube metal temperature does not exceed the code limitations. For vacuum heater tubes where the tube metal temperatures are above those specified in the code, a design pressure of 10.4 barg shall be used at the design temperature. In addition, the tube wall thickness shall not be less than schedule 40 average wall.

- 2.5.1.2 Fired steam superheater heaters and all coils in steam superheating, steam generation and water preheating services together with their associated equipment, shall be designed in accordance with ASME Boiler and Pressure Vessel Code, Section I.

- 2.5.1.3 Process coils, located inside the radiant or convection section, shall be designed in accordance with [API RP 530](#). The practical limit to minimum thickness for new tubes shall be as specified in [API RP 530](#).

Where rupture strength is applicable, the 100,000 hour design life values given in [API RP 530](#) for the carbon steels, the ferritic alloy steels and the type 321 and 347 stainless steels shall apply.

- * 2.5.1.4 For process coil manifolds and fittings with single or multiple openings, located in the radiant or convection section, the design shall be subject to approval by BP.

Fittings with access plugs or flanges should be protected from the hot flue gases (in header boxes or installed external to the heater) as should manifolds and fittings with multiple connections where it is not possible to calculate the process flow split or the metal temperatures.



- 2.5.1.5 Process coil components, manifolds, crossovers and piping located outside the radiant or convection section (inside and outside header boxes) shall be designed in accordance with [ASME/ANSI B31.3](#).
- * 2.5.1.6 Where materials intended for the above applications are either not listed in the relevant code or their service temperature falls outside the range of allowable code stress values, then their allowable stress values shall be subject to approval by BP. (Refer also to 3.1.3 of this Specification).
- 2.5.2 Non-Pressure Parts
- 2.5.2.1 Steel stacks and their lining shall be designed in accordance with [BS 4076](#) or an equivalent national code.
- 2.5.2.2 All structural and supporting steelwork, including tube supports, ducting, platforms, stairs and ladders shall be designed in accordance with either [BS 5950](#) or [BS 449](#) or an equivalent national code.
- Proprietary equipment, such as air to flue gas preheaters, shall also meet the above requirements.
- * 2.5.2.3 All non-pressure parts not covered in 2.5.2.1 and 2.5.2.2 above shall be designed to vendor's standard practice; however, the basis for design shall be subject to approval by BP.

3. TUBES

3.1 General

- 3.1.1 Tube wall thickness for coils shall be determined in accordance with the procedures specified in section 2.5 of this Standard.

The tube design pressure shall be at least equal to the maximum inlet pressure to the heater or that required by the code. The maximum inlet pressure shall take into account possible increases of pressure above normal inlet pressure caused by internal coke formation, any restriction of the flow area downstream of the heater, variations in operating conditions or 'blocked in' system conditions, etc.

(Substitution for [API 3.1.1](#))



- 3.1.2 The design shall take into consideration stresses by differential thermal expansion along the length of the tubes (between adjacent interconnected tubes) and to the stresses resulting from the weight of the tubes and their contents.

(Addition to [API 3.1.2](#))

- * 3.1.3 The maximum calculated tube metal temperature shall be determined in accordance with procedures specified in the design codes noted in 2.5 unless otherwise approved by BP. The design tube metal temperature, as a minimum, shall be at least 28°C (50°F) above the maximum calculated tube metal temperature (or that required for the code, whichever the greater). The maximum calculated tube metal temperature shall be based on the maximum local heat flux density as noted in 2.1.4. The effect of the temperature gradient across the wall thickness of the tubes shall be considered in the design.

In accordance with 1.7.2 of [API 560](#), the vendor shall provide calculations to substantiate the calculated tube metal temperatures and tube stresses.

With regard to definition of design metal temperatures, a number of factors need to be considered.

1. *High Temperature Tensile and Creep Properties.*

[API RP530](#) contains graphs of Stress v Design Metal Temperature. The tensile properties govern design unless the temperature is high enough for creep to become a consideration. Therefore either the elastic allowable stress is used as the basis for design, or the 100,000 hr rupture allowable stress is used.

The maximum temperature that can be tolerated in design for each individual material is therefore dictated by the stress in the material and either the relevant elastic allowable stress or the rupture allowable stress. There is therefore not a single maximum temperature for each material, since the temperature will depend on the level of applied stress.

For example, in a catalytic reformer furnace, the tubes may be 2 1/4Cr 1Mo, and these will be subject to high temperature and high pressure and therefore ultimate life is controlled by creep. For a vacuum furnace, where tubes may be 5 Cr 1/2Mo, although the temperature is high, the pressure is low and therefore the stresses are low, and hence creep is not a normal problem.

2. *Scaling Temperature.*

In addition to the design based on material properties mentioned above, it is important that furnace tube materials do not run above the scaling temperature, otherwise rapid metal loss can occur leading to very short lives. [API RP530](#) gives limiting design temperatures to avoid scaling for each of the normal furnace tube materials.



For example, the 5Cr 1/2Mo vacuum furnace tubes mentioned above, whilst not suffering from creep because of the low stress, nevertheless can be subject to failure because of scaling. If internal coking occurs, this will lead to increasing temperatures which may eventually exceed the scaling temperature, after which time, lives may be short as a result of oxidation.

3. Internal Coking

The above two temperature constraints are directly based on property limitations of the material in terms of high temperature strength and oxidation resistance. From a process viewpoint however, it is also necessary to minimise temperatures to limit coke formation to acceptable levels. If too high temperatures are run, then excessive coking may occur leading to failure due to scaling as mentioned above or otherwise if furnace tube integrity is to be maintained, the need to shut down the furnace to enable decoking to take place, thereby limiting plant availability.

The allowable design metal temperatures and design stresses for tubes manufactured from other materials shall be subject to approval by BP.

(Substitution for [API 3.1.3](#))

The 28°C (50°F) margin above the calculated tube metal temperature is specified for the following reasons:-

- (a) *It is very difficult to establish the flux and process flow distribution in the radiant section of a heater.*
- (b) *The fouling/coking rates in heater tubes are not usually known.*

Thus there is a margin required between the calculated metal temperatures and the design tube metal temperatures.

On some heaters such as catalytic reformers or hydrogen reformers it is not always possible (because of tube metallurgy) to insist upon the 28°C (50°F) margin. Where this is the case, the vendor should provide details of how the tube side flow maldistribution, fouling and combustion side flux distributions have been estimated.

N.B. On all units where coking is expected, the design tube metal temperature should be estimated 'back' from the installed tube wall thicknesses, the specified corrosion allowances and the design pressures.

- 3.1.4 Where helical or circular coils are formed from more than one tube length, the tube lengths shall be butt welded prior to manipulation.

(Addition to [API 3.1.4](#))

- 3.1.8 The preparation of the ends and the butt welding of tubes and/or pipes in heaters shall comply with BP Group [GS 118-5](#).

(Addition to [API 3.1](#))



- 3.1.9 Each tube shall be marked for identification in accordance with BP Std Drawing S-1258. **Attention is drawn to the avoidance of colour code painting of austenitic type steels.** This avoids embrittlement at high temperatures by zinc, aluminium or low melting point alloys in the paint.

(Addition to [API 3.1](#))

3.2 Extended Surface

- 3.2.1 For heaters having horizontal tubes in the convection section, studs or helical fins may be used. In heaters having vertical tubes in the convection section and which are to be fired on liquid fuels, studs shall be used as the form of extended surface.

(Addition to [API 3.2.1](#))

Studs, solid and segmented fins are acceptable for most applications. Segmented fins should not be used where considerable fouling is expected.

3.2.2 Table 2 - Extended Surface Materials

Materials for the extended surfaces on convection tubes shall be specifically selected for the expected operating conditions.

The temperature of carbon steel fins shall not exceed 45 °C (850°F) at the hottest point, except during steam-air decoking.

If Type 400 alloy fins are to be used, the material shall be 11/13 %Cr to [ASTM A240 Type 405 or 410S](#).

(Addition to [API 3.2.2](#) Table 2)

3.2.3 Table 3 - Extended-Surface Dimensions

For oil fired and combination oil and gas fired heaters the maximum fin density shall be 118 per m. (3 fins/in.), the fins shall not be less than 1.5 mm (0.06 in.) thick at the thinnest section or more than 25 mm (1 in.) high.

For gas fired heaters the maximum fin density shall be 157 per metre (4 fins/in.), the fins shall not be less than 1.5 mm (0.06 in.) thick at the thinnest section or more than 25 mm (1 in.) high.

(Part substitution [API 3.2.3](#) Table 3)

3.2.4 Extended-surface tubes may be used provided:-

- (a) their use is restricted to the convection section of the furnace,
- (b) 110% of the theoretical extended surface is installed to allow for fouling,
- (c) there are three rows of bare convection tubes between the extended surface tubes and direct radiation from the combustion chamber.

Where extended surfaces are used, all the requirements of this Specification, in particular 2.1.4, shall be met with the heater at the designed thermal output both in the clean and fouled condition.

(Addition to [API 3.2](#))

3.3 Materials

Table 4 - Tube Materials and ASTM Specifications

NOTE :-

Where coils are to be expanded into headers, tube only shall be specified. For all-welded coils, pipe or tube may be used, whichever is the most economical, but the dimensional requirements for welding specified in BP Group [GS 118-5](#) shall apply.

(Addition to [API 3.3](#) Table 4)

Carbon - 1/2 %Mo materials shall not be used.

(Modification to [API 3.3](#) Table 4)

3.3.1 To avoid stress corrosion cracking, all austenitic steels shall be supplied in the solution heat-treated (fully- softened) condition.

Where austenitic steels in Grades Type 321 or 347 are to be exposed to H₂/H₂S/hydrocarbon conditions above a metal temperature of 40 °C (750°F), the solution heat-treated pipe shall be given a final thermal stabilising treatment at 90 °C - 950° C (1650°F - 1740°F) for 4 hours. This is to minimise intergranular attack from polythionic acids.

Stainless steel welded components shall be given a stress relief heat treatment after welding as specified in BP Group [GS 118-7](#).



Where austenitic stainless steels are used for attachments, fittings, shields etc., which are outside the scope of Tables 4 and 6 of [API 560](#), they shall be supplied in the solution annealed condition to avoid problems of sigma phase embrittlement.

(Addition to [API 3.3](#))

4. HEADERS

4.1 General

4.1.1 All headers shall meet the requirements specified in Section 2.5 of this Specification.

(Qualification of [API 4.1.1](#))

- * 4.1.2.1 All 90 degree or 180 degree bends in the furnace coils ,whether cast, formed or forged, shall be one-piece seamless. Other cast or forged fittings shall be one-piece seamless or fabricated from standard forged seamless fittings, as approved by BP. Formed and forged bends shall be in accordance with [ANSI B16.9](#) or [ANSI B16.11](#).

(Addition to [API 4.1.2](#))

- * 4.1.3 Heater tubes for crude duty, vacuum duty and thermal cracking duty shall have (where applicable) plug type headers installed at the ends of selected tubes even where steam air decoking facilities are provided. The position, type and number of plug type headers shall be subject to approval by BP.

(Addition to [API 4.1.3](#))

The use of plug headers is no longer recommended for all the tubes. However, internal inspection may be required in heaters with coking duties. It is suggested that 2 or 3 plugs be installed in each process pass where coke laydown or tube corrosion/erosion is expected (Shield tubes and tubes where vaporisation commences). The positions should be discussed and agreed with the vendor.

4.1.4 The minimum thickness of all headers and fittings inside the heater shall be at least equal to the minimum thicknesses of tubes to which they are attached.

(Addition to [API 4.1.4](#))



4.2 Plug-Type Headers

4.2.3 This section is superseded by the requirements of section 4.1.2.

(Substitution for [API 4.2.3](#))

4.2.4 This section is superseded by the requirements of section 4.1.3.

(Substitution for [API 4.2.4](#))

4.2.9 Plug headers shall be of the weld-on type.

The plugs shall be numbered and an anti-scuffing compound shall be used on the header plugs. The design of the plugs/headers shall be such that the plugs cannot be dropped down the inside of the tubes.

The welding of cast plug headers shall be carried out in the fabrication shop, leaving forged return bends for welding on site.

(Addition to [API 4.2](#))

4.3 Return Bends

4.3.1 All bends inside the fire box shall be selected for the same design pressure and temperature as the connecting tubes.

(Substitution for [API 4.3.1](#))

4.3.2 All bends located inside the heater (fire and header boxes) shall be of the same material grade (or higher) as those of the connecting tubes.

(Addition to [API 4.3.2](#))

4.4 Materials

Table 6 - Plug Header and Return Bend Materials

Carbon - 1/2 %Mo materials shall not be used.

(Modification to [API 4.4](#) Table 6)



5. PIPING, TERMINALS AND MANIFOLDS

5.1 General

5.1.3 Piping, terminals and manifolds located outside the firebox shall meet the requirements specified in section 2.5 of this Specification.

(Substitution for [API 5.1.3](#))

5.1.4 *Normally inspection openings are not required; if they are, then access for introscope inspection should be provided. Terminal flanges can be used if the removable pipework has to be used for other reasons e.g. swing elbows for steam air decoking. The problem with disturbing terminal flanges is the risk of flanges leaking when they are re-instated.*

* 5.1.7 Arrangements and details of the inlet and outlet piping will be supplied by the purchaser and shall be subject to approval by the heater vendor.

(Addition to [API 5.1](#))

* 5.3 Materials

Internal or external cross overs between radiant and convection coils may be provided. In either case they shall be readily accessible for non-destructive inspection procedures. All cross-over lines shall be fabricated in the same material as the radiant coils except that for ethylene, methanol and steam reformer furnaces, the line thicknesses and materials shall be subject to approval by BP.

(Substitution for [API 5.3](#))

* 5.4 Bolts and Joints

Jointing material shall comply with BP Group [GS 142-7](#) and bolting shall comply with BP Group [GS 142-9](#). It is essential, however, to choose bolting that is compatible with the flange material in respect of the thermal expansion characteristic. For duties above 65 °C (1200°F), bolting shall be subject to approval by BP.

Addition to [API Section 5](#))

6. TUBE SUPPORTS

6.1 General

* 6.1.1 Unless otherwise approved by BP.

(Addition to [API 6.1.1](#))



In order to ensure that the horizontal radiant section intermediate tube supports and top tube supports for vertical radiant tubes are removable, the plus 111° C (200° F) on the bridgewall temperature can be reduced for the sections of the supports protected by the tubes.

- 6.1.5.1 The design temperature of end tube sheets in the radiant and convection sections shall be at least equal to 28°C (50°F) above the maximum expected temperature of the process fluid in the tubes that they are supporting. All end tube sheets shall be designed in accordance with 6.1.5.2 through to 6.1.5.4.

(Substitution for [API 6.1.5.1](#))

- * 6.1.7 Radiant tube supports shall be replaceable without removing the tubes, with the exception of helical coil supports, where their method of replacement shall be subject to approval by BP.

(Addition to [API 6.1](#))

Helical coil supports are behind the tube, hence, it is difficult to replace them without removing the tubes. The vendor/contractor should ensure that the tubes plus the supports can be easily removed from the heater shell (crane access or a lifting beam is required).

6.2 Loads and Allowable Stress

- 6.2.1.1 Tube supports shall meet the requirements specified in section 2.5 of this Specification. When considering the tube support design, account shall be taken of the possible maldistribution of loads between the tube supports.

(Substitution for [API 6.2.1.1](#))

6.3 Materials

- 6.3.1 Table 8 - Maximum Design Temperatures for Tube Support Materials.

Alloy cast iron materials shall not be used. 25% Cr 12% Ni shall be used only where the tube supports can be replaced without removing the tubes. Otherwise, 25% Cr 20% Ni shall be used. The maximum temperature for 18% Cr 8% Ni tube supports shall be 760°C (1400°F).

(Qualification to [API 6.3.1](#))

- * 6.3.2 Note 1

Insulated tube supports shall not be used unless approved by BP.

(Qualification to [API 6.3.2](#) Note 1)



Insulation can fall off the tube supports and should not be used to avoid vanadium attack in new heaters (50% Cr 50% Ni tube supports should be installed). Insulation could be used on existing heaters where the alternative is expensive.

For continuous firing of fuel oil containing high vanadium and sodium, 50% Cr - 50% Ni material (should be IN 657 type) should be used for the supports. Refractory coatings can fall off and should only be used on existing applications or where there is infrequent use of high vanadium fuels.

- 6.3.3 Where tube supports and guides are subject to corrosive conditions, a corrosion allowance shall be added to the calculated thicknesses.

(Addition to [API 6.3](#))

7. REFRACTORIES AND INSULATION

7.1 General

- * 7.1.1 Design temperature of the outside casing surface of the radiant and convection sections shall not exceed 65°C (149°F) at an ambient temperature of 15°C (60°F) in still air, unless otherwise approved by BP.

(Part-Substitution of [API 7.1.1](#))

The 65°C (149°F) casing temperature has been established for personnel protection reasons. If personnel protection is provided or the casing is not accessible during normal operation, then this casing temperature can be increased provided there is economic justification for the increased heat losses, e.g. the ducting downstream of the heater or air preheater to the stack.

N.B. The vendor/contractor should ensure that the paintwork on the casing is suitable for the maximum temperature that the casing can attain (with still air and the maximum ambient air temperature).

For most of the heater casings the 65°C (149°F) temperature limitation is not a problem but there could be difficulties on the roof and floor. Obviously the casing temperature can be increased downstream of the heat exchanger where the furnace efficiency is not affected, provided the casing cannot be touched during normal operation. The paintwork must be suitable for the casing temperatures.

- 7.1.3 Minimum service temperature for refractories shall be 980°C (1800°F) in the radiant and shield sections and 675°C (1250°F) for all other sections.

(Part-Substitution for [API 7.1.3](#))

- 7.1.8 Refer also to sections 9.1.7, 9.2.8 and 10.2.5.

(Addition to [API 7.1](#))



7.2 Brick and Tile Construction

- * 7.2.3 Casings and steelwork behind refractories shall be protected by Hydrotemp anti-corrosion compound or an equivalent approved by BP, when refractory bricks are used.

(Addition to [API 7.2](#))

7.3 Castable Construction

- * 7.3.1 Monolithic floor, wall and arch construction shall be 1.2.4 volumetric mix of lumnite-haydite-vermiculite or an equivalent approved by BP. The casings and steelwork behind the castable material shall be protected by Hydrotemp anti-corrosion compound or an equivalent approved by BP.

(Part-Substitution for [API 7.3.1](#) first paragraph)

Any castable equivalent should conform to [ASTM C155](#) or [C401](#) as relevant.

7.4 Block Insulation

- 7.4.2 Where monolithic hot face insulation is used its thickness shall be not less than 75 mm (3 in).

(Addition to [API 7.4.2](#))

- 7.4.3 Block insulation shall not be used as a back-up material for ceramic fibre linings.

(Addition to [API 7.4.3](#))

- * 7.4.5 Casings and steelwork behind block insulation shall be protected by Hydrotemp anti-corrosion compound or an equivalent approved by BP.

(Substitution for [API 7.4.5](#))

7.5 Ceramic Fibre Construction

- 7.5.1 The back-up layer of ceramic fibre shall be a minimum of 25 mm (1 in) thick 96 kg/m³ (6 lb/ft³) density, needled material.

(Part-Substitution for [API 7.5.1](#))



- 7.5.6 Where local turbulence is expected and the average flue gas velocity exceeds 3 m/sec (10 ft/s) or where the average flue gas velocity without turbulence exceeds 9.1 m/s (30 ft/s), wet-pack type blankets shall be utilised for the hot face layer to improve resistance to shredding.

The hot face layer of all hosing's shall consist of wet-pack type blanket as a minimum.

(Substitution for [API 7.5.6](#))

- * 7.5.7 Where ceramic fibre construction is used, a layer of metal foil shall be installed as a vapour barrier. Stainless steel foil shall be used when the fuel fired contains more than one percent by weight of sulphur or one and a half percent by volume of hydrogen sulphide. The location of the metal foil shall ensure that its operating temperature is above flue gas acid dew point and below its maximum allowable temperature during all operating conditions of the heater. The foil thickness shall be greater than 0.08 mm (0.003 in).

Casings and steelwork behind ceramic fibre insulation shall be protected by an internal protection coating to prevent corrosion. This coating shall be subject to approval by BP (Hydrotemp anti-corrosion compound or equivalent would be acceptable).

(Substitution for [API 7.5.7](#))

- 7.5.8 Ceramic fibre construction shall not be used within the coiled section of convection banks.

(Substitution for [API 7.5.8](#))

- 7.5.9 Not less than two layers of ceramic fibre blanket shall be installed with compressed joints for the backing layers and overlapped joints for the hot face layers. All joints in successive layers shall be staggered to avoid a direct heat leakage path to the casing.

(Substitution for [API 7.5.9](#))

- 7.5.10 All ceramic lining design and installation details shall be subject to approval by the 'specialist' lining installer/supplier.

(Addition to [API 7.5](#))



7.7 Thermal and Acoustic Insulation

External thermal insulation and internal/external acoustic insulation shall comply with the requirements of BP Group [GS 152-1](#).

(Addition to [API section 7](#))

8. STRUCTURES AND APPURTENANCES

8.1 General

8.1.1 Structural steel shall be designed in accordance with the applicable provisions specified in section 2.5 of this Specification.

(Substitution for [API 8.1.1](#))

* 8.1.2 A structure or part of a structure shall be designed to resist all applicable dead and live loading, including but not restricted to, the following:-

- (a) Structure dead loads (including fireproofing and insulation).
- (b) Imposed loads.
- (c) Weight of process contents of test fluids, also process contents resulting from credible operation.
- (d) Lifting equipment including dynamic effects.
- (e) Dynamic or periodic loads resulting from operating machinery.
- (f) Wind, snow and ice loading.
- (g) Seismic loading.
- (h) Settlement.
- (i) Thermal loading - particularly for structures subject to high temperature variation and long structures.
- (j) Pipe anchor and surge condition loads.
- (k) Loads arising during construction and erection.
- (l) Lack of fit.

The loads shall be considered both separately and in realistic combinations.

Wind loading for sites in the United Kingdom shall be in accordance with [BS CP 3: Chapter V: Part 2](#).

If no national standard exists, wind loading shall be submitted and shall be subject to approval by BP.

Reduced wind loading may be used for erection, assembly and test conditions using the statistical factor S3 in [BS CP 3: Chapter V: Part 2](#). A two-year period of exposure will normally be suitable for erection conditions and test conditions. A value of S3 of 0.77 shall be considered a practical minimum.

Imposed loadings shall comply with [BS 6399: Part 1](#), [BS 449](#) or [BS 5950](#) as appropriate, except as described below.

The following imposed loads shall be used in the design of structures:-

- (a) Platforms, walkways and stairways (not supporting any equipment and not intended as working platforms):-

2.5 kN/m² (52 lb/ft²),

- (b) Working platforms and platforms over which heavy equipment may be transported or stored:-

5.0 kN/m² (104 lb/ft²),

or the actual superimposed equipment load, whichever is the heavier.

Seismic loading will be specified by the purchaser.

The design shall take account of the need for stability of both the whole structure and the individual elements at all stages of erection.

Temporary bracing shall be checked for the effects of all loadings that may arise during erection, including loads due to the erection equipment and its operation.

Temporary bracing shall be clearly identified on the erection drawings. Clear instructions shall be provided, stating the appropriate stage of erection for the removal of any temporary supports or rigid fixings for joints required during erection.

For loading combinations with seismic load, an increase in the permissible stresses may be allowed; however, proposals shall be submitted and shall be subject to approval by BP.

(Substitution for [API 8.1.2](#))

8.2 Structures

8.2.4 Stitch welding of the heater casing or the structural members to the heater casing shall not be permitted where the stitch welding is exposed to the atmosphere.

The heater casing shall be seal-welded to the greatest possible extent and shall be visibly leak-tight when tested with smoke bombs under a positive pressure of at least 12 mm (1/2 in) water gauge. The vendor shall provide all the equipment necessary for this test. Where the heater is shop prefabricated into one or more sections then each section shall be shop smoke bomb tested. See also 13.5.

(Addition to [API 8.2.4](#))

* 8.2.7 Supporting structures for the heaters shall be designed so that fire protection can be installed.

The amount of passive fire protection applied will be not less than that required to achieve a 2-hour rating when tested to [BS 476: Part 8](#), [ASTM E119](#) or [ISO 834](#).

Design proposals for heater and associated equipment fire protection shall be subject to approval by BP at an early stage in the design.

(Substitution for [API 8.2.7](#))

It is essential that any fire protection installed does not cause overheating of the furnace casing or structure. (Insulation outside of heaters can cause thermal expansion problems).

8.2.9 To allow for supporting the convection section tubes in case of tubesheet failure, where the convection section is mounted above the radiant section, a minimum gap of 600 mm (2 ft) shall be left between the top of the horizontal structural member at the bottom of the convection section and the centre line of the shock tubes.

(Addition to [API 8.2](#))

* 8.2.10 Where forced-draught fans are fitted, the heater structure, casing and ducting shall be designed to withstand the full fan pressure, unless otherwise approved by BP.



Where induced-draught fans are fitted, and where induced and forced-draught fans are provided, the furnace casing, structure and ducting shall be capable of withstanding, without damage, the maximum positive or negative pressure that can be exerted by the fan or fans when the relevant dampers are in their maximum possible 'open' or 'shut' positions unless otherwise approved by BP.

Where the maximum positive fan pressure results in excessive additional steelwork then special damper designs or pressure relief doors may be proposed, and shall be subject to approval by BP.

(Addition to [API 8.2](#))

At times it is not economical to design the heater so that it can withstand the maximum positive or negative pressures the fans can produce (no load pressures). Where this is the case, it is essential that either:

- (a) *Pressure relief doors are installed (these are a source of air inleakage).*
- (b) *Minimum stops are fitted to the dampers in order to limit the pressure conditions in the heater to that which the structure and casing plates etc. can withstand.*

N.B. On start-up the negative pressure exerted by the induced draught fan can be much higher than the normal condition.

8.3 Header Boxes, Doors and Ports

8.3.1 Header boxes shall conform to the requirements of 8.3.1.1 through 8.3.1.6.

(Substitution for [API 8.3.1](#))

8.3.1.2 On heaters equipped with tube plug-type headers, the header box doors shall be fitted with substantial hinges and fastening devices that are not susceptible to jamming by corrosion. Header box doors that are in a vertical plane but have horizontal hinges, shall be arranged to open downwards. Other heaters shall have header boxes fitted with removable, bolted and gasketed panels.

Provision shall be made for panel removal. Where panels are too large to be removed by one person, inspection doors shall be provided.

(Substitution for [API 8.3.1.2](#))



8.3.1.3 Header boxes shall be bolted and seal welded (internally) to the heater structure. Access shall be provided for seal weld removal with the tubes in position.

(Addition to [API 8.3.1.3](#))

8.3.1.4 Header boxes shall be designed to permit maximum accessibility for maintenance and, where necessary, for welding. Removable panels shall be provided for withdrawal and replacement of radiant and convection tubes where this cannot be effected through the header box doors. Split panel joints shall not be installed where the tubes pass through the header casing.

(Addition to [API 8.3.1](#))

* 8.3.1.5 All header box doors shall be made airtight by the use of fitted ceramic fibre joints of a type which shall be subject to approval by BP.

(Addition to [API 8.3.1](#))

Ladder tape thick enough to seal non machined surfaces should be used (minimum thickness 3 mm)

8.3.1.6 Header boxes shall be provided with drain holes screwed 4 0mm (1 1/2 in) and plugged.

(Addition to [API 8.3.1](#))

The heater drains need to be piped up where continuous condensation is expected in the heater boxes, i.e. where the return bends operate below the dew point of the flue gas.

8.3.2 Doors and ports shall be provided as described in 8.3.2.1 through 8.3.2.9 of this Specification.

(Substitution for [API 8.3.2](#))

8.3.2.1 Two access doors shall be provided in each radiant chamber and above each convection section. The doors should be at least 60 0mm (24 in) square opening.

Where this cannot be accommodated due to heater design, the minimum opening dimension shall not be less than 450 mm (18 in).

(Substitution for [API 8.3.2.1](#))



- 8.3.2.2 Access doors with a minimum opening of 600 mm x 600 mm (24 in x 24 in) where ducting size permits, shall be provided in flue ducts at suitable positions. Side entry at duct floor level is preferred where this can be readily arranged.

(Substitution for [API 8.3.2.2](#))

- 8.3.2.5 Sufficient peep-doors shall be provided in the vertical walls of each radiant section to permit:-

- (a) a clear view of each main burner during light-up. The burner controls shall be located within burner arms-length of the peep-hole giving a view of that burner.
- (b) a check to be made of the flame lengths and the evenness of firing. In the case of vertically-fired heaters, this will require peep-holes at higher levels than those given in (a). A minimum of two such additional peep-holes shall be provided at each upper level, giving views of the flames, and at right angles to each other. Access to these upper peep-holes shall be provided by means of a platform and a ladder.

Both the above requirements are best met by peep-holes sited along the length of the tubes. Together, the peep-holes shall give a view of all parts of the furnace walls and tubes, including those convection tubes exposed to radiant heat. Where furnace tube wall temperatures are to be measured by radiation pyrometer, the location and numbers of peep-holes shall provide for this. Peep-holes in side walls shall be at least 100 mm x 180 mm (4 in x 7 in).

Other peep-holes shall be provided as appropriate, to permit:-

- (i) a check for flame impingement on the furnace tubes,
- (ii) a check to be made of tube distortion.

(Substitution for [API 8.3.2.5](#))

- 8.3.2.6 Bolted and gasketed openings shall be provided for examination of the convection tubes during operation and shall give a view between the banks.

(Addition to [API 8.3.2.](#))



- 8.3.2.7 Pipework and equipment shall not be installed where it will obscure peep-holes or prevent access to them.

(Addition to [API 8.3.2.](#))

- 8.3.2.8 Peep-holes, including the floor holes, shall have air-tight self-closing doors or covers. The floor hole covers shall be readily operable from grade.

Where peep-holes are fitted with glass or equivalent, self-returning internal metal peep covers shall be fitted and means provided to:-

- (a) replace the glass with the heater on load,
- (b) keep the glass clean.

These covers shall be protected with insulation.

(Addition to [API 8.3.2](#))

- 8.3.2.9 Bolted and gasketed inspection panels shall be provided local to dampers installed in the combustion air and flue gas ducts.

(Addition to [API 8.3.2](#))

- 8.3.3 Unless otherwise specified or required by statutory regulations, explosion doors shall not be fitted.

(Addition to [API 8.3](#))

The size of explosion door typically fitted to a fired heater has been found on occasions to provide inadequate protection and they are a source of air-inleakage.

8.4 Ladders, Platforms and Stairways

- 8.4.1 6. At all isolating plates, combustion air and flue gas inspection panels.

(Addition to [API 8.4.1](#))

- * 8.4.1 7. Platforms with ladder access shall be provided at all places requiring access for maintenance, e.g. instrument connecting points such as thermowells, draught-gauge tapping points and flue gas analyser probes, all transmitters, flue gas sampling points, smoke detectors, header boxes, sootblowers and dampers. Provision of platforms shall be kept to a minimum by suitable grouping of these points. Platforms shall be sized and be structurally suitable for maintenance activities.



With BP approval and, where economic reasons dictate, access to thermowells, transmitters and tapping points may be by temporary means, provided they are at a height of no more than 6 m (20 ft) above grade or 2 m (7 ft) directly above an available permanent platform. Refer also to section 11.5 of [API 560](#).

(Addition to [API 8.4.1](#))

- 8.4.1 8. Platforms with stairway access shall be provided at all places that require regular operation access. These should include peep-holes at hearth level and at the burner lighting valves.

(Addition to 8.4.1)

- 8.4.3 4. Firing platforms, where burner withdrawal is carried out or portable ignitors used, shall be 1.8 m (6 ft) wide.

(Addition to [API 8.4.3](#))

- 8.4.4.1 Platforms shall normally be of open-type metal (either rectangular pattern or pressed steel) although chequer plate flooring may be permitted where there is a danger of petroleum liquids or liquefied petroleum gases falling from high level onto lower platforms or equipment.

(Addition to [API 8.4.4](#))

- 8.4.4.2 Open-type metal flooring shall conform to BS 4592 and should be hot dip galvanised.

Rectangular pattern, open-type, metal flooring is normally preferred with main bearing bars approximately 5 mm (3/16 in) thick and with an anti-slip serrated top surface. The width of the opening between load-bearing bars should not exceed 25 mm (1 in).

(Addition to [API 8.4.4](#))

- 8.4.4.3 Removable panels shall not exceed 75 kg (1.5 cwt) in weight.

(Addition to [API 8.4.4](#))

- 8.4.4.4 Stair treads shall be open-type metal, similar in pattern to main flooring, with visible slip resistant front edges and hot dipped galvanised finish.

(Part-Substitution for [API 8.4.4](#))



- 8.4.4.5 The steel used for steel flooring and stair treads shall conform to [BS 4360](#) Grade 43A or an equivalent national standard.

(Addition to [API 8.4.4](#))

- 8.4.5 Interconnected platforms shall have alternative escape routes to grade. Platforms at high level on grouped heaters shall be interconnected wherever practicable.

All firing platforms or burner control platforms shall have at least two escape routes to ground level, one of which shall be a stairway direct to grade.

(Qualification of [API 8.4.5](#))

- 8.4.7 All ladders shall be in accordance with BP Std Drawings S-0808M, S-1969 and S-1970.

(Addition to [API 8.4.7](#))

- 8.4.8 Stairways shall be in accordance with BP Std Drawing S-0806M.

(Substitution for [API 8.4.8](#))

- 8.4.10 Handrails shall be in accordance with BP Std Drawing S-0807M.

(Addition to [API 8.4.10](#))

- 8.4.11 Any platform serving one group of burners shall be at one level.

(Addition to [API 8.4](#))

- 8.4.12 Steel stacks shall be provided with all-welded caged ladders in accordance with BP Std Drawing S-0808M, and with painting-trolley rings.

(Addition to [API 8.4](#))

8.5 **Materials**

- 8.5.1 Materials used in the fabrication of fired heater structures and platforms shall conform to the following specification or an equivalent national standard:-

- (1) Structural steel [BS 449](#) Part 2 - [BS 4360](#) - [BS 5950](#).
- (2) Plate [BS 449](#) Part 2 - [BS 4360](#) - [BS 5950](#).



- (3) Structural bolts [BS 4190](#).
- (4) Precision steel bolts [BS 3692](#).
- (5) HSFG bolts [BS 4395](#).
- (6) Steel ladders, platforms and trolley rings including bolting and other attachments shall be hot dip galvanised.

(Substitution for [API 8.5.1](#))

8.6 Furnace Sealing (Addition to API Section 8)

- * 8.6.1 Where tubes, the tubeskin thermocouples and any other pieces of equipment pass through the heater casing or the header boxes from inside to outside the heater, the holes in the casing/header boxes should be fitted with fabric bellows or equivalent sealing device in order to prevent air inleakage or flue gas leaking out of the heater. The use of sealing plates or packed glands shall be subject to approval by BP.

Packed glands are acceptable where there is movement in one plane. In most instances these can only be on tube skin thermocouples.

- 8.6.2 Where tube guide pins on the bottom of the vertical hairpin tubes pass through the floor of a heater, the holes on the bottom of the furnace shall be sealed against air inleakage using fabric 'socks' or an equivalent sealing device.

9. STACKS, DUCTS AND BREECHING

9.1 General

- 9.1.1 Stacks may be either free-standing or mounted on the heater.

(Addition to [API 9.1.1](#))

Where it is not possible to fit diametrically opposed inlets to the stack, then baffle walls need to be fitted.

- * 9.1.6 Flue ducting shall be arranged above grade level and supported and anchored so as to permit freedom of movement for thermal expansion and contraction.

If man entry to ducting is necessary for cleaning/maintenance activities, the ducting should be externally ribbed to give required loading bearing capacity in the event of low temperature corrosion of the duct sheeting.



Expansion joints within the ducting shall be provided so that no significant forces are transmitted to the heater, stack, fans or waste heat boiler. Packed gland type expansion joints shall not be used where air leakage can affect the furnace efficiency.

In the design of flue duct openings, compensating steel shall be extended a sufficient distance above the opening to ensure a smooth stress flow around the opening. For all connections and attachments, specific attention shall be given to reducing stress concentrations.

Design of duct entries shall be subject to approval by BP.

(Addition to [API 9.1.6](#))

9.1.7 The top 10 m (33 ft) of the stack internal lining shall be of acid-resistant material.

(Addition to [API 9.1.7](#))

* 9.1.9 Large spaces in the base of free standing stacks below the lowest duct entry shall be isolated by the provision of gas-tight false floors. The space below floor in contact with the flue gases shall be ventilated to prevent overheating. Foundations shall also be protected from excessive heat. All stacks shall have access in the base at grade level and means of entry through the false floor. Requirements regarding additional access doors, baffle walls and flue entries will be separately specified by BP.

All free-standing stacks shall be fitted with a drain connection of not less than 50 mm (2 in) diameter.

(Substitution for [API 9.1.9](#))

9.1.10 Breeching located over horizontal convection zones shall be provided with not less than one offtake for every 9.1 m. (30 ft) length of convection section.

(Addition to [API 9.1.10](#))

9.1.11 *Inlet air plenum dampers should not be used instead of draught control dampers on units with tall stacks (greater than 10 metres high) or where heaters are used for continuous operation over long periods (high draught can result in burner instability and air leakage).*

9.1.12 Sectional steel stacks with flanged and bolted joints shall have their flanges stiff, true and flat and normal to the longitudinal axis around one complete circumference. Maximum bolt spacing on flanges shall be 75 mm (3 in) and all bolts shall be 19 mm (3/4 in) minimum diameter.



Friction grip bolts shall not be used. Suitable transition shall be made from the stiff flange rings to the more flexible shell. Not less than two conductors or bonds shall be spaced equally around the perimeter and across each flanged joint to provide adequate continuity for lightning protection.

(Addition to [API 9.1](#))

- 9.1.13 Specific lightning conductor provisions are not required on welded steel stacks. Earthing of the structure and, where fitted, guy lines, shall be as recommended by [BS 6651](#), or equivalent national standards. Earthing of structures shall be in accordance with BP Std Drawing S-0596M.

(Addition to [API 9.1](#))

- 9.1.14 Stacks may require facilities for flue gas sampling and smoke and temperature measurement.

(Addition to [API 9.1](#))

- 9.1.15 Stacks shall be provided with ladders as specified in 8.4.12.

(Addition to [API 9.1](#))

9.2 Design Considerations

- 9.2.1 The design shall be in accordance with the applicable provisions specified in section 2.5 of this Specification.

- 9.2.1.1 Stacks and ducts shall be sized to meet the requirements of section 2.2.4 of this Specification. The flue gas quantities used in sizing stacks and ducts shall be derived from section 2.2.4 of this Specification which includes for 5% air-inleakage, e.g. across air preheaters, at fan and damper shafts, at peep-doors and miscellaneous openings, etc.

The vendor shall specify the air-inleakage included if he expects more than 5% for the complete system.

- * 9.2.1.2 The minimum height above grade level and the exit gas velocity will be specified by the purchaser.

BP require that if the minimum stack efflux velocity is not specified by the statutory authorities, then the minimum exit area of the stack shall be such as to give a minimum flue gas exit velocity of 9 m/s (30 ft/s) when all units that are connected to the stack are at their 100% design loads at design excess air.

(Substitution for [API 9.2.1](#))



- 9.2.2 For installations in the UK, wind loading shall be calculated in accordance with [BS CP3: Chapter V: Part 2](#) and [BS 4076](#). For other areas, the appropriate national codes shall be used.

(Qualification of [API 9.2.2](#))

- 9.2.5 Steel stacks shall incorporate a corrosion allowance appropriate to a 20 year design life.

(Addition to [API 9.2.5](#))
(except in conditions noted below)

- * 9.2.8 Unless otherwise agreed with BP, stacks, ducts and breeching shall be lined throughout (except in conditions noted below) and the lining shall be capable of withstanding, without damage, temperatures of 540°C (1000°F), or a temperature 16 °C (300°F) above the normal maximum operating flue gas temperature, whichever is greater, and of being raised from cold to the design operating temperature at the rate of 5 °C (100°F) per hour. Specific attention shall also be given to the possibility of low temperature conditions occurring, in particular, below acid dew-point level, and the possible effects of resultant condensation within the stack.

If the operating conditions are such that an unlined stack appears suitable, then proposals may be submitted and they shall be subject to approval by BP.

Where a common stack is used for both heaters and steam boilers and is not provided with separate flue bores, the lining shall be suitable for the most stringent start-up and operation conditions.

(Addition to [API 9.2.8](#))

Unlined stacks should only be installed when the process in the tubes is non combustible e.g. steam superheaters or inert gas heaters or where the stacks are very short and easily replaced e.g. grade mounted stacks about 15 m high. The reason for internally lining the stack is in response to concern over the possibility of damage arising from a heater fire. The insulation acts as fire-proofing.

- 9.2.12 Dampers shall be provided, where necessary, for control, isolating and bypass purposes. Isolating plates shall be provided where access is needed for maintenance and inspection of heaters or heater ancillaries, e.g. air preheater, waste heat boilers, etc., whilst the heater or heaters which are connected to the common flue gas duct or stack continue to operate. Where isolating plates are provided, the plates shall be positioned as close to the common flue duct as is practicable. Where a



number of flue gas ducts are directly connected to a common stack, isolating plates shall also be provided as close to the stack as possible for each duct entry.

Where flue gas bypass dampers are provided, the dampers shall have a zero, or an acceptably low, guaranteed leakage rate under normal operating conditions, i.e. closed. Where necessary, the bypass dampers shall be quick-acting in order to protect uncooled boiler tubes, and/or allow for induced-draught fan failure, etc.

(Substitution for [API 9.2.12](#))

- 9.2.13 Flue duct and stack dampers that are used to control furnace draught shall be of the contra-rotating multi-louvre type, set in a channel frame, and provided with position indicators visible from the operating position at grade. Special attention shall be given to blade clearances in the frame and adjacent ducting under operating conditions.

(Addition to [API 9.2.13](#))

- 9.2.15 Damper shafts shall be supported in self-aligning bearings grease packed or otherwise lubricated and sealed, suitable for high temperature and located in external pillow blocks.

Adequate allowance shall be made for the relative expansion of the components. For reasons of energy conservation, air cooled shafts where air enters the flue gas duct, shall be avoided. The vendor shall submit for BP review, his calculations for the relative expansion of the components.

(Substitution for [API 9.2.15](#))

- * 9.2.16 Ducting shall be arranged so that the isolating plates operate vertically downwards to shut. Where a vendor considers that alternative arrangements would permit significant economies to be made, proposals shall be submitted and they shall be subject to approval by BP.

The plates shall be designed to minimise distortion due to uneven heating when in the closed position.

The housing for the isolating plates shall be designed so that the slideways or grooves in the flue passage do not choke with corrosion products or other debris.

(Addition to [API 9.2](#))

9.3 Allowable Stresses

Where [BS 4076](#) is used as the stack design code then the equivalent allowable stresses shall be used.

(Qualification of [API 9.3](#))

9.4 Static Design

Where the requirements of [BS 4076](#) are more stringent than the requirements of section 9.4 then the requirements of [BS 4076](#) shall be followed.

(Qualification of [API 9.4](#))

9.5 Wind-Induced Vibration Design

- * 9.5.4 To avoid wind-excited sway oscillations and the consequent possibility of fatigue in the chimney shell or damage to linings, all steel stacks shall be fitted with helical strakes or other suitable wind spoilers approved by BP, unless it can be shown that the critical wind speed is greater than the design wind speed. The critical wind speed is the speed at which the frequency of vortex shedding is equal to the natural frequency of the stack.

(Qualification of [API 9.5.4](#))

9.6 Materials

- 9.6.1 Any materials used in the unit construction shall meet the requirements of the specified structural design codes.

(Qualification of [API 9.6.1](#))

- 9.6.2 Any nuts and bolts used shall meet the requirements of the specified codes.

(Qualification of [API 9.6.2](#))

10. BURNERS AND AUXILIARY EQUIPMENT

10.1 Burners

- 10.1.1 The shape of the combustion chamber and the number and disposition of burners shall be chosen to give good distribution of heat to the radiant tubes.



Where relevant:-

- (a) natural draught burners shall comply with BP Group [GS 122-2](#),
- (b) forced draught burners shall comply with BP Group [GS 122-3](#).

(Addition to [API 10.1.1](#))

* 10.1.2 For natural draught burners the minimum clearance specified in Table 11 of this Specification shall be provided.

For forced draught burners the clearances shall be subject to approval by BP.

(Substitution for [API 10.1.2](#))

For forced draught burners, the burner clearance should satisfy Figure T. For vertical firing, the burner flame length at design heat release should desirably be less than half of the height of the heater. In addition, the clearance between the end of the flame and the centre line of the nearest tube should be at least 1.2 m (4 ft).



TABLE 11
MINIMUM CLEARANCE FOR NATURAL DRAUGHT BURNER OPERATION

Gas, Oil or Combination Firing

Maximum Heat Release Per Burner	MINIMUM CLEARANCE			
	A	B	C	D
	Vertical to Centreline Roof Tubes or Refractory (Vertical Firing)	Horizontal to Centreline wall Tubes from Burner Centreline	Horizontal from Centreline of Burner to Unshielded Refractory	Between Opposing Burner (Horizontal Firing)
	million Btu/hr (kw)	ft (metres)	ft (metres)	ft (metres)
3.5 (1025)	11 (3.4)	2.75 (0.8)	2.0 (0.6)	16 (4.9)
6 (1758)	16 (4.9)	3.25 (1.0)	2.5 (0.8)	22 (6.7)
8 (2343)	20 (6.1)	3.75 (1.1)	3.0 (0.9)	28 (8.5)
10 (2930)	24 (7.3)	4.25 (1.3)	3.5 (1.1)	32 (9.8)
12 (3516)	28 (8.5)	4.75 (1.4)	4.0 (1.2)	36 (11.0)
14 (4102)	32 (9.8)	5.25 (1.6)	4.5 (1.4)	40 (12.2)

For horizontal firing, the distance between burner centreline and the roof tube centreline or roof refractory shall be 50% greater than the distances specified in Column B.

(Substitution for [API 10.1.2 Table 11](#))



- * 10.1.3 Each burner shall be sized either for 110% of its design load or such that the design load on the furnace can be carried with one burner out for cleaning, whichever is the greater, unless otherwise approved by BP.

(Substitution for [API 10.1.3](#))

When there are four burners or less there can be a problem with sizing the burners such that the design load on the furnace can be carried with one burner out. The problem is that when all the burners are in operation they will be firing at reduced capacity and reduced combustion efficiency. This problem can be overcome by:-

- (a) *not sizing the burners to carry the furnace load with one out. This could cause production limitations on important heaters,*
- (b) *increasing the number of burners,*
- (c) *installing burners that will operate at the requisite overload. This means gas and oil firing in the same burner and a bigger forced draught fan on forced draught heaters or higher draught on natural draught heaters.*

For a single fuel furnace, a high fuel supply pressure is required.

The burners need to be tested at their overload conditions.

- 10.1.4 On single burner heaters, fired on liquid fuel only, the burner shall be fitted with an auxiliary gun which is to be fired during main gun cleaning, in order to maintain continuity of firing at the design load.

(Qualification of [API 10.1.4](#))

Single burner 'oil only' fired heaters should only be used where the heater operation is not essential for the plant operation (oil leakage/spillage is expected at some time during the heater operation and thus could result, if only one burner is fitted, in the need to shut down the heater in order to clean the burner).

- * 10.1.5 Each burner shall be provided with a continuously-operating fixed gas pilot arranged to light all the fuels and, where practicable, waste gas supplied to the main burners, unless otherwise approved by BP. The pilots shall be easily visible in normal operation and be sized to remain alight under all practicable heater draught and pressure conditions.

Proposals for pilot burners for very high temperature heaters such as ethylene, methanol or steam reformer heaters, where large numbers of burners are in close proximity to hot refractories, shall be subject to approval by BP.

(Substitution for [API 10.1.5](#))



Where there is a large number of burners in close proximity to hot refractory (on ethylene crackers and some hydrogen reformers) it is very unusual to install a pilot burner system.

- 10.1.7 Satisfactory combustion shall be achieved with each of the specified fuels over a range of firing loads from maximum heat release to 33% of its 100% design load for natural draught and from maximum heat release to 27.5% of its 100% design load for forced draught burner.

Satisfactory combustion is defined as a flame shape appropriate to the furnace, no flame impingement on the process tubes, no visible smoke and the specified limitations in flue gas emissions at the exit from the radiant section, all at the specified excess air and at the specified loads.

(Addition to [API 10.1.7](#))

The stack emissions must meet the statutory authority requirements.

- 10.1.11 Safety interlocks shall comply with BP Group [GS 122-2](#) and BP Group [GS 122-3](#).

(Substitution for [API 10.1.11](#))

- 10.1.12 Where foul gases or waste gases are disposed of by burning in a process furnace, such gases shall be piped separately to some or preferably all of the main burner registers and injected into the main flame through separate gas nozzles. The distribution to the main burners shall be selected according to the quantities of such gases being burnt relative to the main fuel flows.

(Addition to [API 10.1](#))

- 10.1.13 All natural draught burners shall be fitted with noise silencer devices.

(Addition to [API 10.1](#))

- 10.1.14 Installation details of the burners and their arrangement shall be subject to approval by the burner supplier.

(Addition to [API 10.1](#))

10.2 Sootblowers (Steam)

- 10.2.1 Sootblowers shall be retractable, with automatic sequential control.

(Substitution for 10.2.1)



10.2.2 A local sootblowing panel shall be provided with:-

- (a) a master switch for the sootblowing sequence operation; also, switches for individual operation or for the by-passing in sequence of the sootblowers,
- (b) indicating lamps showing the operation of each sootblower,
- (c) automatic control of the sootblower steam master valve,
- (d) an interlock to prevent sootblower operation until the piping has reached preset temperature, with a lamp to show 'drainage complete',
- (e) an alarm if the sootblower has not retracted within a stipulated time,
- (f) retraction of the sootblower on low steam pressure or overload condition.

The build-up of condensate in the supply lines shall be avoided by the provision of adequate automatic drains and warming-through connections.

(Addition to [API 10.2.2](#))

10.2.4 The sootblowers shall be spaced as follows:-

- (a) The maximum allowable distance between sootblowers in a sootblower lane is 2 m (6 ft 6 in).
- (b) The maximum allowable number of rows of extended surface tubes that can be covered by one sootblower is:-
 - (i) 3 against the flow of flue gases,
 - (ii) 4 with the flow of flue gases.

(Substitution for [API 10.2.4](#))

10.2.5 *Stainless steel shrouds should not be used where vanadium containing fuels are being fired.*

10.3 Fans and Drivers

- 10.3.2 Fans shall be designed for optimum efficiency at normal heat release and design excess air (normal operating points).

Forced draught (FD) fans shall be sized on the combustion air flow requirements as defined in section 2.2.4 of this Specification together with any additional requirements to account for air leakage as referred to in section 9.2.1.1.

Induced draught (ID) fans shall be sized on the flue gas quantities produced from the combustion air flow requirements as defined in section 2.2.4 of this Specification together with the requirements of section 9.2.1.1.

The flue gas temperature in the fans shall be assumed to be at least 15°C (30°F) above the calculated temperature with the furnace on 100% design load.

The static head required for FD and ID fans shall be consistent with the system losses at the combustion and flue gas quantities as defined above.

FD fans shall be capable of supplying sufficient air to the burners so that the heater can operate at 100% design duty and design excess air with one burner out of commission.

(Substitution for [API 10.3.2](#))

- 10.3.3 The complete fan installation, fans, drivers, etc., shall be suitable for 24-hour per day continuous operation for a period not less than that specified between major overhauls.

The mechanical design temperature for ID fans shall be at least 5°C (100°F) above the maximum expected operating temperature under all conditions of furnace operation.

(Qualification of [API 10.3.3](#))

- 10.3.7 Forced and induced draught fans should preferably be of the centrifugal flow type with backward curved blades; however, radial blades shall be considered for induced draught fans where heaters are firing residual fuel oils or fuels with a tendency to form fouling products. For larger fan capacities blades shall be of aerofoil design.

(Addition to [API 10.3](#))

10.3.8 On fans driven by fixed speed drivers, control of the total flow should be provided by adjustable vanes in the inlet to the fan. They shall fail open. A discharge damper shall also be supplied in addition to the inlet vane controller in order to achieve accurate control throughout the entire operating range of the heater.

(Addition to [API 10.3](#))

* 10.3.9 Induced and forced draught fans and their drivers shall be freely accessible for maintenance, and mounted on foundation blocks separate from the heater at or near ground level, unless otherwise approved by BP.

(Addition to [API 10.3](#))

Usually induced draught (ID) and forced draught (FD) fans can be installed at grade without any major cost implications. However, on some heaters this is not possible. Where fans are mounted on structures, then:-

(a) *The structures should be designed to cater for the fan vibrations and be rigid enough to prevent structure movements causing fan damage. The vendor needs to advise the precautions taken in the structural design offered.*

(b) *Anti vibration mounting pads should be installed between the fan/motor support steelwork and the structure.*

10.3.10 Where forced draught is to be used, each heater shall be provided with one forced draught fan with a shut-off damper downstream of the fan.

(Addition to [API 10.3](#))

10.3.11 All fans shall be provided with a control room panel alarm, sensed on the shaft on the fan side of the driver coupling to indicate operational failure.

(Addition to [API 10.3](#))

10.3.12 Electric motor drivers shall comply with the relevant requirements of BP Group [GS 112-3](#) or [GS 112-4](#).

(Addition to [API 10.3](#))

10.4 Damper Controls

10.4.1 *All control dampers should be designed to fail safe.*

- * 10.4.3 Provision shall be made for furnace draught control dampers to be individually operable by hand from grade level (even if automatic damper operation is fitted) and the mechanism shall be arranged to lock in any position. The operating mechanism shall give positive drive in both the opening and closing directions but shall be counterbalanced to fail in the open position. Cable-operated mechanisms shall be provided with adequate tensioning devices.

Limit stops shall be installed on all control dampers. These stops shall:-

- (a) prevent complete closure of the dampers,
- (b) prevent the damper blades exceeding their fully open positions.

The type (fixed or variable) and position of these stops shall be agreed with BP.

(Substitution for [API 10.4.3](#))

Limit stops are required on control dampers in order to prevent complete closure of the dampers. The difficulty is that at times it may be necessary to override these stops. If there is a fire, then:-

- (a) *Where natural draught burners are installed the draught control damper may have to be closed in order to minimise the quantity of air being pulled into a furnace and enable the smothering steam to put out the fire.*
- (b) *On forced draught burners the air flow control damper may have to be closed.*

N.B. : Any minimum stop must be secure. For example, it is no use fitting a minimum stop on the cable of draught control dampers because the cable can stretch or be replaced.

10.5 Air to Flue Gas Preheaters (Direct Preheaters)

(Addition to [API Section 10](#))

- 10.5.1 The combustion air leakage rate, if any, shall be specified by the vendor in his proposal together with the maximum guaranteed leakage rate over the guarantee period. Combustion air leakage rates shall be taken into consideration when assessing overall fuel, utility and power consumptions over the payout period.
- 10.5.2 Air to flue gas preheaters shall be equipped with steam sootblowers and/or water washing devices regardless of the fuel fired.
- 10.5.3 Combustion air and flue gas ducting to/from the air preheater shall be designed to ensure that even flow distribution to/from the air preheater



is maintained during all operating conditions. The air preheater supplier shall approve the ducting design relative to his equipment.

10.5.4 Where sulphur bearing fuels are fired, then the vendor shall include in his proposal the data specified in section 2.1.8 of this Specification, where applicable.

10.5.5 Where regenerative type air preheaters are proposed, the following shall be noted:-

- (a) Where sulphur bearing and/or fuels with a tendency to form fouling products are fired, then a sight port shall be supplied at the air inlet duct in order that the 'cold end' elements may be visibly inspected for signs of corrosion or fouling. Similarly a hatch shall be provided in the housing to permit replacement of 'cold end' elements, if necessary.
- (b) The vendor shall provide full details of the heat transfer matrix together with the plate profiles proposed. Where non-fouling fuels are to be fired then 'open' profile plates may be proposed; however, where fuels to be fired have a tendency to form fouling products then 'closed' profile plates only shall be proposed in order to improve efficiency of sootblowing.
- (c) Details of rotor bearings and lubrication system shall be provided. Water cooled bearings should be avoided if possible.

* 10.5.6 Where recuperative type air preheaters are proposed, the following conditions shall apply:-

- (a) Recuperative type air preheaters shall normally be grade mounted with the flue gas flow passing over the tubes in a downflow direction. Other configurations, including air preheaters mounted above heater convection sections, shall not be proposed without prior approval from BP.
- (b) The vendor shall provide full details of the heat transfer surface together with 'bare' and 'extended' surface data, tube size(s) etc., and sealing details for plates, cast iron and glass tubes, where applicable.
- (c) With reference to section 10.5.2 of this Specification, facilities for cleaning metal surfaces shall be provided in addition to the water washing facilities for cleaning of the 'cold end' glass tubes (when provided).



- (d) The outlet flue gas duct shall be provided with a water wash effluent connection and the ducting design shall ensure that no liquid carryover onto the ID fan will occur if 'on-line' water washing.
- (e) The preheater shall be visibly leak tight when 'shop' tested with smoke bombs under a positive pressure of at least 100 mm water gauge (4 inch water gauge) on the air side.

10.5.7 Control of the air preheater combustion air outlet temperature shall be achieved by provision of a combustion air by-pass. Combustion air temperature control shall not be achieved by the provision of a flue gas by-pass. Where it is necessary to provide a flue gas by-pass in order to meet the requirements of section 2.2.4, this by-pass shall only be operable in the fully open or fully closed position.

10.6 Combustion Air Ducting (Addition to [API Section 10](#))

10.6.1 All combustion air ducting and ancillary equipment shall be in accordance with the applicable provisions specified in section 2.5 of this Specification.

10.6.2 The layout and size of all ducts and plenum chambers shall allow proper distribution of combustion air to the burners and ancillary equipment (e.g. air preheater).

The layout and size of all ducts and plenum chambers shall be agreed with the relevant vendors (burner or air preheater).

Where the combustion air ducting serves more than one burner then the design of the combustion air ducting shall ensure:-

- (a) an equal air mass flow rate within a tolerance of + or - 3% of the average air flow rate to each burner, evenly distributed to each burner windbox,
- (b) that the air velocity in the distribution ducting between each burner (windbox) does not exceed 9 m/s (30 ft/sec) at furnace design conditions,
- (c) individual burners are removable with the other burners in operation.

10.6.3 Duct turns (bends) shall be kept to a minimum and be equipped with suitable vanes and splitter plates where necessary.

- 10.6.4 Ducting shall be arranged above grade level and supported and anchored so as to permit freedom of movement for thermal expansion and contraction. Expansion joints within the ducting shall be provided so that no significant forces are transmitted to the heater burner wind boxes, air preheater, fans or ancillary equipment. Packed gland type expansion joints shall not be used where air inleakage can affect the furnace efficiency.
- * 10.6.5 Underground combustion air ducting shall not be proposed unless prior approval is obtained from BP.
- 10.6.6 Ducting shall be of welded steel construction with a minimum thickness of 6 mm (1/4 in) and shall be suitably lined, where applicable, to meet the acoustic and heat conservation requirements.
- 10.6.7 Forced draught combustion air flow control should be provided and achieved in principle by control of the FD fan speed or inlet vane control at the fan inlet (see 10.3.8). Where combustion air dampers are utilised for air flow control, they shall be of the contra-rotating multi-louvre type, set in a channel frame and provided with position indicators visible from the operating position at grade.
- * 10.6.8 Forced draught combustion air flow measurement shall be provided and achieved by provision of a BP approved flow measurement device usually installed in the suction side of the FD fan. However, where the fan supplies air to more than one furnace, or to a furnace with more than one cell, air flow measurement devices shall be installed in each duct to each furnace and/or cell.
- 10.6.9 Isolating plates for combustion air ducting shall meet the requirements of section 9.2.16 of this Specification.

10.7 Electrical Equipment and Hazard Classification

(Addition to [API Section 10](#))

Electrical equipment included in the vendor's scope of supply shall be in accordance with the purchaser's specification.

***11. INSTRUMENT AND AUXILIARY CONNECTIONS**

As a general requirement details of the number, type and location of all instrument and auxiliary connections for equipment within the vendors scope of supply will be specified by the purchaser and shall be subject to approval by BP.



As a minimum requirement, the connections or nozzles specified in [API 560](#), as amended below are required.

(Addition to [API Section 11](#))

11.1 Flue Gas and Air

11.1.1 Flue Gas and Combustion Air Temperature

11.1.1.5 Connections shall be provided in the common burner ducting of each burner group.

(Addition to [API 11.1.1.5](#))

11.1.2.8 Connections shall also be provided at the following locations:-

- (a) at the inlet and throat of each venturi tube,
- (b) at the inlet and outlet of each fan,
- (c) at each burner.

(Addition to [API 11.1.2.8](#))

11.1.4 Combustion Air Flow

Refer to sections 10.6.8 and 11.1.2.8.

(Addition to [API 11.1](#))

11.4 Tube-Skin Thermocouples

Tube-skin thermocouples shall be provided in accordance with the following requirements:-

* 11.4.1 Radiant coil tube skin metal.

Thermocouples for this duty shall be fabricated, attached and tested, in accordance with BP Std Drawings S-1974 and S-1975. Fired boilers and all heaters on duties where coking may be expected shall have at least two skin thermocouples per pass. Other heaters shall have skin thermocouples on selected passes. The thermocouples shall be positioned where maximum metal temperatures are anticipated and shall be subject to approval by BP (see also section 8.6 of this Specification).

11.4.2 Where reverse steam-air decoking is intended, additional skin thermocouples shall be installed in each pass, on one of the shock tubes.



- 11.4.3 Special attention shall be given to the relative movements of the thermocouple connections and the heater shell.
- 11.4.4 Tube metal temperatures on cracking and reforming furnaces with cast tubes shall be measured by portable pyrometers; skin thermocouples should be avoided.
- 11.4.5 Where heater coils are installed in their casings prior to shipment to site, all applicable tube skin thermocouples shall also be fully installed.

(Substitution for [API 11.4](#))

12. SHOP FABRICATION AND FIELD ERECTION

12.1 General

- 12.1.4 Heater steel shall be fabricated in accordance with applicable provisions of BP Group [GS 118-3](#).

(Substitution for [API 12.1.4](#))

- * 12.1.5 Process coils, manifolds and crossovers located inside the heater firebox or headerbox shall be fabricated in accordance with [ANSI B31.3](#), and the requirements of BP Group [GS 118-5](#) and [GS 118-7](#). The fabrication of high alloy centrifugal cast tubes shall be agreed with BP.

(Substitution for [API 12.1.5](#))

- 12.1.6 All process piping, manifolds and crossovers external to the heater shall be fabricated in accordance with BP Group [GS 118-5](#) and [GS 118-7](#).

(Addition to [API 12.1](#))

- 12.1.7 Steam superheater, boiler coils, water preheating coils and associated equipment shall be fabricated in accordance with Parts PG and PW of the ASME Boiler and Pressure Vessel Code, Section I, [ANSI B31.3](#) and the requirements of BP Group [GS 118-5](#) and [GS 118-7](#).

(Addition to [API 12.1](#))

12.2 Steel Fabrication

- 12.2.1 Welders for structural steel fabrication shall meet the requirements specified in BP Group [GS 118-3](#).

(Substitution for [API 12.2.1](#))



12.2.5 Welding filler materials for the processes listed in 12.2.5.1 and 12.2.5.2 shall be as specified in BP Group [GS 118-3](#).

(Substitution for [API 12.2.5](#))

12.2.5.3 All structural welding, including ductwork, shall be in accordance with BP Group [GS 118-3](#).

(Addition to [API 12.2.5](#))

12.2.18 Prior to fabrication, the dimensions of structural members shall be checked. The alignment of top faces of members which support equipment shall also be checked.

(Addition to [API 12.2](#))

12.2.19 Components which are to be connected together at site by either welding or bolting (e.g. radiant and convection sections, stacks, platforms etc.) shall preferably be shop fitted (trial erected) prior to delivery. Where such components cannot be shop fitted, template shop fitting shall be carried out. Fit-up procedures shall be documented and witnessed by the purchaser's inspector.

(Addition to [API 12.2](#))

12.2.20 All platform and ladder attachments to heaters and stacks shall be shop welded or bolted.

(Addition to [API 12.2](#))

12.3 Coil Fabrication

12.3.8 Coils shall be progressively blown out as each weld is completed and care exercised in order to prevent entrance of extraneous matter.

(Addition to [API 12.3](#))

12.4 Painting and Galvanising (Heater Steel, Structural Steel and Flue Gas and Air Ducting)

* 12.4.1 Painting and treatment of metal surfaces exposed to the atmosphere shall be in accordance with BP Group [GS 106-2](#) and the following requirements where the surface temperatures are below 120°C (248° F):-

(a) Blast clean to SA 2-1/2 near white metal 50 - 75 micron profile.



- (b) One coat of zinc silicate primer dry film thickness 65 microns.
- (c) Two coats of modified aluminium silicone paint 15 microns per coat. The modified aluminium silicone to provide an air drying finish suitable for temperatures up to 300°C (572°F).

Additionally, the top 10 m (33 ft) of the outer surface of the stack shall be coated for protection against acid attack resulting from possible downwash of gases, in addition to protection from atmospheric corrosion. The precise type of coating (including film thickness, surface preparation, etc.) shall be proposed by the vendor in his tender together with the paint manufacturer's confirmation regarding its suitability for the operating conditions and subject to approval by BP (refer also to 9.1.7).

Identification colours for the fired heater tubes shall be in accordance with BP Std. Drawing No. S-1258.

(Substitution for [API 12.4.1 and 12.4.2](#))

12.4.3 Refer also to 8.5.1 item (6) of this Specification.

(Addition to [API 12.4.3](#))

12.7 Proprietary Equipment

Where applicable, fabrication of all proprietary equipment shall be in accordance with section 12.

(Addition to [API Section 12](#))

12.8 Name Plates

All pressure part assemblies as defined in section 2.5.1 of this Specification shall be provided with a name plate in accordance with BP Group GS 132-1.

(Addition to [API Section 12](#))



13. INSPECTION AND TESTING

13.2 Weld Inspection

- 13.2.1 Steam superheater, boiler coils, water preheating coils and associated equipment shall be inspected and tested in accordance with Parts PG and PW of the ASME Boiler and Pressure Vessel Code, Section I, [ANSI B31.3](#) and the requirements of BP Group [GS 118-5](#) and [118-7](#).

(Substitution for [API 13.2.1](#))

- 13.2.2 Process coils, manifolds and crossovers located inside or outside the heater firebox or headerbox shall be inspected and tested in accordance with [ANSI B31.3](#) and BP Group [GS 118-5](#) and [GS 118-7](#) except where modified by 13.2.2.1 through to 13.2.2.5.

(Substitution for [API 13.2.2](#))

- 13.2.2.3 The examination of butt welds shall meet the requirements of [ANSI B31.3](#) and BP Group [GS 118-5](#) and [GS 118-7](#).

(Substitution for [API 13.2.2.3](#))

13.4 Inspection of Other Components

- 13.4.1 Inspection of heater steelwork shall be in accordance with the requirements of BP Group [GS 118-3](#).

(Substitution for [API 13.4.1](#))

- 13.4.1.1 No major weld, or the adjacent steelwork, shall be coated until the inspector has approved the weld; however, temporary protection by coating with boiled linseed oil is acceptable.

(Addition to [API 13.4.1](#))

- 13.4.3 As a minimum the vendor shall submit the following procedures to the purchaser:-

- (a) Tolerance check of fin or stud height and thickness/OD.
- (b) Dimensional check of extended surface density and pitching.
- (c) Dimensional check of tube ID to ascertain variation in tube ID, if any, due to heat input during the welding of extended surface to tube.



- (d) Suitable random tests to ascertain integrity of the extended surface to tube weld.

The vendor shall submit to the purchaser a sample of each extended surface tube type, that is for:-

- (e) Each metallurgical combination of extended surface and tube material,
- (f) Each combination of extended surface fin thickness/stud diameter.

Each sample shall be cross-sectioned and micro-etched in order that the extended surface to tube weld may be visually inspected.

(Addition to [API 13.4.3](#))

- 13.4.5 All lifting lug welds shall be examined 100% by liquid penetration and magnetic particle test methods.

(Addition to [API 13.4](#))

- 13.4.6 A programme for the inspection of ceramic fibre insulating blanket and other ceramic fibre products shall be submitted by the vendor for BP/purchaser review.

(Addition to [API 13.4](#))

13.5 Testing

13.5.1 Pressure Testing

- 13.5.1.1 All pressure parts shall be hydraulically tested to meet the following requirements:-

- (a) For coils with headers and removable plugs: the pressure test shall be twice the maximum process inlet pressure or 1.5 times the decoking steam inlet pressure, whichever is the greater.
- (b) For all other coils the minimum pressure test shall be equal to 1.5 times the coil design pressure multiplied by the ratio of the allowable stress at 38°C (100°F) to the allowable stress at the design tube metal temperature.
- (c) For pressure parts designed to meet the ASME Boiler Code, hydrostatic testing to the requirements of ASME Boiler and Pressure Vessel Code, Section 1, shall be carried out.



- Notes:-
- (1) The maximum test pressure shall be limited to the extent that the weakest component shall not be stressed beyond 90% of the material's yield strength at ambient temperature.
 - (2) The flange rating requirements are not exceeded at the test temperature.
 - (3) The yield stress of the inlet and outlet header manifolds is not exceeded at the test temperature.
 - (4) The hydrostatic test pressure shall be maintained for a minimum period of one hour in order to test for leaks.

(Substitution for [API 13.5.1.1](#))

13.5.1.3 Water used for testing shall be clean and potable. For pressure parts containing austenitic stainless steel in the construction, the test water shall have a chloride content of less than 30 ppm. Where it is not possible to test with water containing less than 30 ppm chloride, normal mains water may be used with the addition of 0.5% solution of sodium nitrate. These pressure parts shall be thoroughly washed out with water containing less than 30 ppm chloride immediately after the test and thoroughly dried.

(Substitution for [API 13.5.1.3](#))

13.5.2 Refractory Testing

13.5.2.1 Refractory and insulating materials shall be tested by the manufacturer in accordance with the relevant ASTM standards and test results submitted to purchaser for review.

(Addition to [API 13.5.2](#))

Relevant ASTM Standards include:-

<i>Cold crushing strength</i>	ASTM C133
<i>Permanent linear change</i>	ASTM C113
<i>Modulus of Rupture</i>	ASTM C133
<i>Thermal conductivity</i>	ASTM C201
<i>Deformation under load</i>	ASTM C16
<i>Pyrometric Case Equivalent</i>	ASTM C24
<i>Heating of specimens</i>	ASTM C865

Normal test requirements after heating and cooling are as given in [ASTM C865](#), for cold crushing strength, bulk density and permanent linear change. Tests given in the other documents listed above are only requested in special circumstances.



13.5.3 Studded Tube Testing

Each length of extended surface tubing assembly shall be randomly inspected by hammer testing or other approved method in order to check the integrity of the extended surface to tube weld.

(Substitution for [API 13.5.3](#))

13.5.4 Burners

Where applicable the burners shall be tested in accordance with the requirements of BP Group [GS 122-2](#) or BP Group [GS 122-3](#).

(Addition to [API 13.5](#))

13.5.5 Fans

Forced and induced draught fans shall be tested in accordance with the requirements of BS 848 Part 1.

(Addition to [API 13.5](#))

13.5.6 Heater Casing and Flue Gas System

The complete heater flue gas system to a point upstream of the stack shall be visibly leak tested after assembly in accordance with section 8.2.4. of this Specification.

(Addition to [API 13.5](#))

13.5.7 Combustion Air System

Forced draught combustion air systems to a point upstream of the burners shall be leak tested after installation at site.

(Addition to [API 13.5](#))

* 13.5.8 Thermal Efficiency

Where thermal efficiency guarantees of the furnace are specified by the purchaser they shall operate in accordance with API RP 532.

(Addition to [API 13.5](#))

13.5.9 Noise



13.5.9.1 The vendor shall provide details of the noise emission octave bands from his equipment, obtained by the methods of test as specified in [EEMUA Publication No. 140](#) or an alternative method of test acceptable to BP.

* 13.5.9.2 Where noise guarantees for the furnace and ancillary equipment are specified by the purchaser, they shall operate in accordance with [CONCAWE Report No. 3/77](#).

(Addition to [API 13.5](#))

* **13.6 Proprietary Equipment**

The vendor shall submit for approval a full inspection and testing procedure for each item of proprietary equipment. Where applicable, the requirements of this section (13) shall be included in the subject procedures.

(Addition to [API Section 13](#))



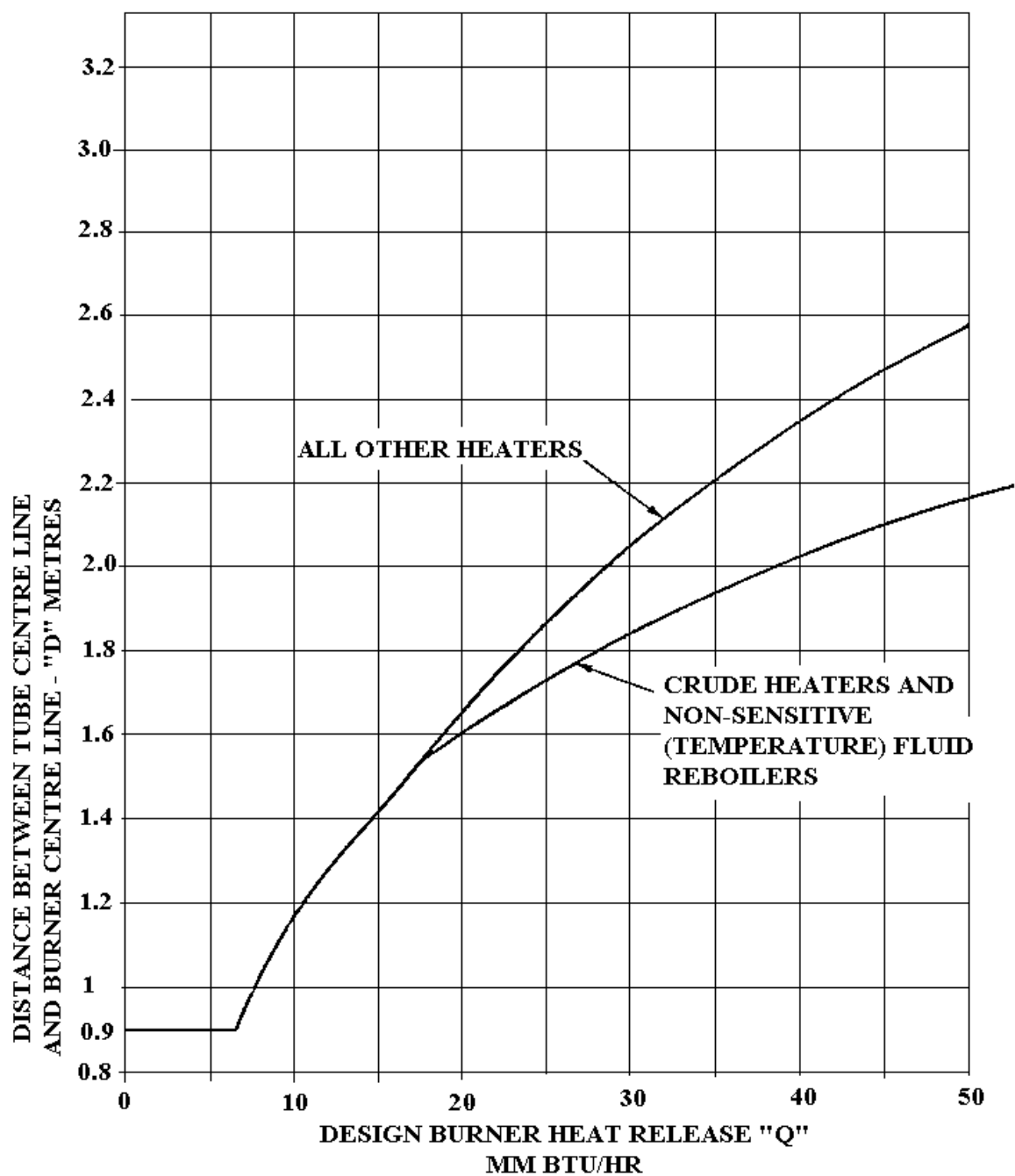


FIGURE T
FORCED DRAUGHT BURNER TUBE CLEARANCES

DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory volume.

Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BS	British Standard
BSI	British Standards Institute
CONCAWE	Conservation of Clean Air and Water - Europe
EEMUA	Engineering Equipment and Materials Users Association
HSFG	High Strength Friction Grip
IEC	International Electrotechnical Commission
ID	Inside Diameter
ISO	International Organisation for Standardisation
OD	Outside Diameter
QA	Quality Assurance
SI	Système International d'Unités



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

International

- [ISO 834](#) Fire-resistance tests - Elements of building construction.
- [ISO 9001](#) Quality Systems - Model for quality assurance in design/development, production, installation and servicing.

British Standards

- [BS 449](#) Specification for the use of structural steel in buildings. Part 2: Metric units.
- [BS 476](#) Fire tests on building materials and structures. Part 8: Test methods and criteria for the fire resistance of elements of building construction.
- [BS 848](#) Fans for general use. Part 1: Methods of testing performance.
- [BS 3692](#) Specification for ISO metric black hexagon bolts, screws and nuts.
- [BS 4076](#) Specification for steel chimneys.
- [BS 4190](#) Specification for ISO metric black hexagon bolts, screws and nuts.
- [BS 4360](#) Specification for weldable structural steels.
- [BS 4395](#) Specification for high strength friction grip bolts and associated nuts and washers for structural engineering.
- [BS 4592](#) Industrial type metal flooring, walkways and stair treads.
- [BS 5950](#) Structural use of steelwork in buildings.
- [BS 6399](#) Loadings for buildings. Part 1: Code of practice for dead and imposed loads.
- [BS 6651](#) Code of practice for protection of structures against lightning.



British Codes of Practice

BS CP 3 Code of basic data for the design of buildings. Chapter V: Loading - Part 2 Wind Loads.

American

ANSI/ASME B16.9 Factory-made wrought steel butt-welding fittings.

ANSI B16.11 Forged steel fittings, socket-welding and threaded.

ANSI/ASME B31.3 Chemical plant and petroleum refinery piping.

ANSI/ASME Boiler and pressure vessel code. Section 1:Power boilers.

API RP 530 Recommended practice for calculations of heater tube thickness in petroleum refineries.

API RP 532 Measurement of thermal efficiency of fired process heaters.

API 533 Air preheat systems for fired process heaters.

API Std 560 Fired heaters for general refinery services. First edition, January 1986.

ASTM E119 Methods for fire tests of building construction and materials.

ASTM A240 Specification for heat resisting chromium and chromium nickel stainless steel plate, sheet, and strip for pressure vessels.

ASTM C16 *Deformation Under Load*

ASTM C24 *Pyrometric Case Equivalent*

ASTM C113 *Permanent Linear Change*

ASTM C133 *Cold Crushing Strength and Modules of Rupture*

ASTM C155 *Classification of Insulating Firebrick*

ASTM C201 *Thermal Conductivity*

ASTM C401 *Classification of Castable Refractories*

ASTM C865 *Heating of Specimens*



BP Group Documents

BP GS 106-2	Painting of Metal Surfaces. (Replaces BP Std 141)
BP GS 112-3	Low-Voltage Induction Motors (Replaces BP Std 221)
BP GS 112-4	High-Voltage Induction Motors (Replaces BP Std 220)
BP GS 118-3	General Standard for Welded Fabrication. (Replaces BP Std 164)
BP GS 118-5	The Fabrication, Assembly, Erection and Inspection of Carbon, Carbon Manganese and Low Alloy Ferritic Steel Pipework to ANSI/ASME B31.3 (Replaces BP Std 167 Part 1 & 2)
BP GS 118-7	Fabrication of Pipework to ANSI B31.3, Part 3: Austenitic and Duplex Steel Pipework, Cupro-Nickel and Nickel Base Alloy Pipework (Replaces BP Std 167 Part 3)
BP GS 122-2	Natural Draught Burners for Fired Process Heaters. (Replaces BP Std 104)
BP GS 122-3	Forced Draught Burners for Fired Process Heaters. (Replaces BP Std 107)
BP GS 132-1	Name Plates. (Replaces BP Std 123)
BP GS 142-7	Supply of Gaskets and Joint Rings for Bolted Flanged Joints (Replaces BP Std 173).
BP GS 142-9	Bolting for Flanged Joints (Unified Inch Series). (Replaces BP Std 175)
BP GS 152-1	Materials for Thermal Insulation of Pipework & Equipment. (Replaces BP Std 172)

EEMUA and other Documents

EEMUA	Publication 140: Noise procedure specification (Formally OCMA Spec. NWG-1).
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BP Std Drawings:

S-0596M	Earthing Electrodes for Use in All Areas and Typical Earthbar Joints and Fixings.
S-0806M	Stairways.
S-0807M	Platforms.
S-0808M	Vertical Ladders and Cage Construction.
S-1258	Identification Colours for Fired Heater Tubes.
S-1969	Safety Gates and Bar for Vertical Ladders.
S-1970	Extensions to Safety Cages on Elevated Vertical Ladders.
S-1974	Tube Skin Thermocouples Installation Details (Hockey Stick and Sliding Gland).
S-1975	Tube Skin Thermocouples Installation Details for Axial Exit.



MAXIMUM AVERAGE HEAT FLUX ON RADIANT TUBES

TABLE Z

Types of Fired Heater	Duty	Tubes	Minimum Mass Velocity		Maximum Average Heat Flux			
					Single Fired Tubes		Double Fired Tubes	
			Kg/s/m2	lb/s/ft2	Kw/m2	Btu/h/ft2	Kw/m2	Btu/h/ft2
Crude	Crude Oil Heater	Vertical	976 1200	200 250	34.7 37.9	11000 12000	52.1 56.8	16500 18000
		Horizontal	732 976	150 200	41.0 44.2	13000 14000	61.5 66.2	19500 21000
Vacuum	Lub. Oil	Horizontal	(I)	(I)	28.4	9000	-	-
	Non. Lub. Oil	Horizontal	(I)	(I)	31.5	10000	-	-
Cat. Reformer	All Gas Heating	Vertical or Horizontal	(II)	(II)	28.4 (2.1/4% Cr 1% Mo)	9000	52.1 (9% Cr 1% Mo)	16500
Cat. Cracker	Liquid	Vertical or Horizontal	(III)	(III)	31.5	10000	-	-
Reboilers	Two Phase Fluid Heating	Vertical or Horizontal	732	150	34.7 (VI)	11000 (VI)	-	-
		Horizontal	732	150	41.0 (VI)	13000 (VI)	-	-
DHT	Gas Heating	Vertical or Horizontal			37.9	12000 (VI)	-	-
Ferrofiner		Vertical or Horizontal	(IV)	(IV)	20.5	6500	-	-
Lub. Oil Unit	Furfural Extract	Vertical or Horizontal	732	150	23.7	7500	-	-
	Raffinate	Vertical or Horizontal	732	150	20.5	6500	-	-
	Propane Deasphalting	Horizontal	732	150	23.7	7500	-	-
Hydrofiner	Two Phase Fluid Heating		732	150	37.9	12000	-	-

Notes to Table Z

- (1) *Not specified but vendor should ensure that the flow regimes are acceptable throughout the heater.*
- (2) *Not Specified: would expect mass velocities in the region of 200 to 250 kg/s.m² (40 to 50 lbs/s.ft²), Limit is skin temperature and flow distribution.*
- (3) *Not specified: would expect cold oil velocities of 1.2 to 2.5 m/s (4 to 8 ft/s).*
- (4) *Not specified: would expect cold oil velocities of 3 to 3.5 m/s (10 to 12 ft/s).*
- (5) *May be limited by tube skin temperature.*
- (6) *If process fluid is temperature-sensitive, flux should be reduced.*

Note: Where possible, velocities should be maintained at 732 kg/s.m² (150 lb/s ft²) at all normal operating loads. It is essential that either an all liquid, bubble or froth, or fully dispersed regime (as judged by the O. BAKER parameters) is maintained at all operating conditions for two phase flows.

