



GS 156-3

WATER TUBE BOILERS

December 1996

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BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING			
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WATER TUBE BOILERS (Replaces BP Engineering Std 211)			
APPLICABILITY		Does not preclude adaptation for other applications	
Regional Applicability:		United Kingdom	
SCOPE AND PURPOSE			
This document specifies general requirements for water tube type steam boilers, i.e. water inside the tubes. It may be used for conventional fired boilers, gas turbine exhaust heat recovery boilers, process heat recovery boilers and other water tube applications, including steam generation within fired process heaters. Its purpose is to lay down minimum fit-for-purpose requirements to give a realistic basis for bid review and avoid previous operating problems.			
AMENDMENTS			
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CONTENTS

Section	Page
FOREWORD	iii
1. INTRODUCTION.....	1
1.1 Scope	1
1.2 Application.....	1
1.3 <i>Quality Assurance</i>	1
2. PERFORMANCE REQUIREMENTS.....	2
2.1 Steam Pressure(s)	2
2.2 Steam Flow(s)	3
2.3 Steam Temperature(s)	4
2.4 Steam Purity.....	5
2.5 Fuel Requirements	6
2.6 Air Pre-Heat.....	7
2.7 Combustion	7
2.8 Emissions to Atmosphere.....	8
2.9 Chimney	8
2.10 Heat Sources	9
2.11 Heat Recovery	9
2.12 Heat Loss from the Boiler Casing	10
2.13 Operation	10
2.14 Utility Consumption.....	10
2.15 Testing	11
3. PROJECT REQUIREMENTS.....	11
3.1 Scope of Supply	11
3.2 Information.....	12
4. DESIGN REQUIREMENTS	16
4.1 Anticipated Life Span	16
4.2 Scheduled Inspection and Maintenance	16
4.3 Reliability	16
4.4 Design of Pressure Parts	16
4.5 Control and Instrumentation	17
4.6 Furnace Design.....	19
4.7 Steam and Water Separation.....	21
4.8 Natural Circulation	21
4.9 Forced Circulation	22
4.10 Forced Draught Burners	23
4.11 Other Burners.....	24
4.12 Fuel Systems.....	24
4.13 FD Fan and Air System.....	26



4.14 Flue Gas System and ID Fan	26
4.15 Drums and Headers	27
4.16 Desuperheaters	28
4.17 Convection Tube Banks.....	28
4.18 Superheaters/Reheaters.....	30
4.19 Economiser.....	31
4.20 Boiler Cleaning.....	31
4.21 Combustion Air Preheater.....	32
4.22 Boiler Cladding.....	33
4.23 Boiler Support Structure.....	33
4.24 Platforms, Stairways and Ladders	33
4.25 Valves	33
4.26 Dampers	34
4.27 Electrical Equipment.....	35
DATA SHEET - OUTLINE SPECIFICATION	36
APPENDIX A.....	37
DEFINITIONS AND ABBREVIATIONS	37
APPENDIX B.....	38
LIST OF REFERENCED DOCUMENTS.....	38



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

This Guidance for Specification defines requirements for the design and procurement of water tube boilers based upon BP's knowledge and experience worldwide.

Application

This Guidance for Specification is intended to guide the purchaser in developing a 'fit for purpose' specification for enquiry or purchase.

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. Resolution of the 'Approval' actions is the responsibility of the purchaser's professional engineer.

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 156-3) 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 principal change from the previous edition (BP Std 211) is a reduction in detailed definition and embodiment of requirements for all water tube applications in a single document.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP Group Recommended Practices, to assist in the process of their continuous improvement.

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



1. INTRODUCTION

1.1 Scope

1.1.1 This Specification defines the general performance, guarantees, equipment and information requirements for water tube boilers in any application. It is applicable to all conventional designs, whether fired or unfired, and should be used as the basis for development of requirements for more specialised designs such as once through and fluidised bed boilers.

1.1.2 The boiler scope of supply shall include all pressure parts and integral pipework within the battery limits given in 3.1. Additional equipment, such as feed water pumps or chimney, which are outwith the direct boiler scope may be added to the total scope of any project as required.

Some sections of this Guidance document may not be applicable in all cases and the purchaser should develop his detailed requirements to exclude irrelevant points.

1.2 Application

1.2.1 This specification does not give detailed requirements for a particular application. The purchaser shall specify in an accompanying document all the requirements necessary to enable the vendor to make an offer.

This Guidance for Specification must be supplemented with the particular detailed requirements for the application as defined by the purchaser's professional engineer. Consultation with a boiler design specialist is recommended in developing the design requirements. This is considered to be most important since BP has suffered significant losses through inappropriate specification even with so called "standard" packaged boilers.

An outline Data Sheet is attached to this Specification to assist in the development of the purchaser's requirements.

1.2.2 Quotations and orders should require compliance with this specification as a condition of purchase. In the event that any vendor does not wish to comply with any aspect of this specification each and every exception should be advised to the purchaser as soon as possible, preferably prior to submission of the quotation.

1.3 Quality Assurance

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 to any free issue materials.

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

2. PERFORMANCE REQUIREMENTS

The purchaser will specify the following data for steam delivery at the main steam isolation valve(s):-

Constraints and penalties that may be applied are outlined for development in the purchaser's detailed specification.

2.1 Steam Pressure(s)

2.1.1 For fired boilers with natural circulation the minimum boiler operating pressure shall be 20 bar. If the application requires steam at less than 20 bar then the boiler shall be designed to supply steam through a pressure reducing station.

This limit has been set based on consideration of :-

- *the mechanical integrity of welded versus rolled tube/tubesheet joints,*
- *steam/water separation in the drum is assisted at higher pressures,*
- *circulation ratio is higher at higher pressure,*
- *design for the recommended maximum limit for heat flux,*
- *need to avoid dynamic instability, which would otherwise need advanced control and additional cost/complexity.*

In addition this provides some flexibility to meet possible future higher pressure demands over the life of the boiler (several sites have benefited from this).

Lower pressure designs may be acceptable but this would require a compensating reduction in heat flux or change to forced circulation, thus impacting on cost. The cost impacts must be assessed in conjunction with a detailed review of the proposed design, and effects on steam distribution pipework, in order to justify operation at a lower pressure.

2.1.2 Boilers without firing control should be fitted with a valve to sustain the boiler pressure in the event of a significant drop in pressure of the steam main.

Without a pressure sustaining valve it is likely that the boiler will be subject to trip due to drum water level excursions during operation.



2.2 Steam Flow(s)

2.2.1 Maximum Continuous Rating (MCR)

The maximum steam mass flow rate shall be guaranteed for each steam pressure level.

In the event of the boiler not meeting this flow the purchaser may elect to either (a) reduce the price to be paid for the boiler, in proportion to the mass flow, or (b) require the vendor, at his own cost, to modify the boiler to achieve the specified flow.

For some projects it may be necessary to define additional cases such as 'design' and 'peak' steam flows. For gas turbine waste heat boilers it will be necessary to consider turbine base and peak loads, ambient temperature variations and effects of different fuels

2.2.2 Average Boiler Load

This value should be specified in order to optimise the amount of waste heat recovery by the boiler. When a specific value has not been determined for a particular project the average should be assumed to be 75% of the MCR.

The average steam flow will effectively limit the size and cost of economiser and air heater surface.

2.2.3 Steam Flow Control Range

Note that turndown is referenced to heat release and not steam flow. The equivalent steam flow turndown generally will be less than the figures quoted. Consideration should be given to all possible operating conditions, commissioning steam blowing, initial start-up, user trip, etc.

2.2.3.1 Steam flow control for fired boilers will be achieved by regulation of burner firing rate as described in the following:-

- (a) Under automatic control during commercial operation.

In the event of there being no particular project requirement the control range shall be 50 to 100 % of the maximum heat release rate using all burners with the normal burner tips.

A wider automatic control range may be beneficial to reduce the need for operator intervention when extended periods of low load operating may be required. The provision of remote control, where the operator can extinguish and light-off burners to maintain steam pressure should also be considered.

- (b) Under manual control during commercial operation.

In the event of there being no particular project requirement the control range shall be 25 to 100% of the maximum heat release rate using all burners with the normal burner tips.

- (c) During start up and shut down.

In the event of there being no particular project requirement the control range shall be down to 12.5% of the maximum heat release rate using normal burner tips.

If the boiler has two or more burners control may be achieved by not operating some of the burners. A start up facility will be required for single burner boilers.

- 2.2.3.2 Any requirement for steam flow control for unfired boilers must be detailed by the purchaser.

2.3 Steam Temperature(s)

- 2.3.1 Steam temperature control for fired boilers will be achieved by spray desuperheating as described below.

- 2.3.1.1 When superheat and/or reheat is required the vendor shall provide all the equipment, including control system, needed to maintain a constant steam temperature.

Any desuperheater system shall automatically maintain the steam temperature within ± 5 deg C of the desired value under steady state conditions, and ± 10 deg C under transient conditions (at the maximum rate of change of firing).

- 2.3.1.2 An auto/manual control station shall be provided in the main control room. The control range should be designed to maintain the steam temperature within the limits given in 2.3.1.1 from 70% to 100% of MCR.

The minimum steam flow for temperature control will have a small effect on capex. Following a detailed review of the application, specific project requirements may permit a narrower control range and allow some cost saving. However a wider control range may be necessary for other applications, although this will often be more expensive.

A wider control range may be advantageous e.g. to permit steam turbine or other plant tests during commissioning and startup. An infrequent requirement should be explored with the supplier as it may be possible to achieve steam temperature by increased firing of higher level burners for short periods.



2.3.1.3 The steam temperature and control range shall be guaranteed.

If the boiler fails to meet these guarantees and the purchaser elects to accept a lower temperature a penalty may be payable by the vendor. The penalty could be set at the equivalent of two years loss of power at the current sales/import unit price.

2.3.1.4 Spray water for desuperheating service should normally be supplied from the boiler feed water pumps. The vendor should provide steam preheating to within 10 deg C of the boiler saturation temperature before injection into the desuperheater.

This preheat level has been set in order to minimise the likelihood of water forming pools on the tube wall or liner. Various commercial desuperheating designs are available and may be acceptable subject to detailed review. Should the level of preheat be shown to incur significant additional costs, a lower level of preheat may be agreed.

2.3.2 Any requirement for steam temperature control for unfired boilers must be detailed by the purchaser. Desuperheating systems should be in accordance with 2.3.1.

2.4 Steam Purity

2.4.1 For each steam pressure level the vendor shall guarantee for all steady state conditions and steam load increases of up to 25% of MCR that:-

(a) The steam silica content shall not exceed 0.02 mg/l.

Higher silica levels may be acceptable for boilers which will not supply steam turbines.

(b) The steam total solids content shall not exceed:-

(i) 1.0 mg/l for steam pressures up to 60 bar.

(ii) 0.5 mg/l for steam pressure in the range 60 to 130 bar.

Above 130 bar the requirements will be subject to agreement between the relevant parties, eg the purchaser, vendor and turbine supplier.

The steam purity leaving the steam drum should permit any superheater to remain in service for at least four years without needing an internal clean and not suffer any mechanical deterioration, or an increase of more than 0.3 bar in steam pressure drop.

2.4.2 The limits on steam solids and silica content shall be attained with the normal range of feed water and boiler water conditions.

These must be defined in the project specification.

- 2.4.3 For each steam pressure level the blowdown water flow rate should be automatically controlled to maintain operation within the normal range of boiler water conditions. The blowdown should be cooled where economic to do so.

The blowdown cooler is best located upstream of the regulating valve in order to minimise vibration and noise.

Note that continuous blowdown may not be necessary in some cases, eg zero solids operation.

- 2.4.4 The vendor shall provide dedicated stainless steel sample lines for superheated steam, saturated steam, boiler water and feed water. The sample connections shall be taken from the top of pipework (to avoid ingress of debris into the sample line) via adequately supported double isolation valves.

Sample lines shall each be provided with appropriate sample coolers and conductivity monitors, having both local and remote indication.

- 2.4.5 Where necessary conductivity monitoring cells shall be protected from the adverse effects of volatile substances such as ammonia, amines, CO₂, etc. In addition provision shall be made for bottle samples to be supplied before and after the protection device to monitor satisfactory operation.

Analyser conductivity readings are affected by volatile substances which dissolve with hydrolysis and partial dissociation into ions. This has the effect of increasing the condensed steam sample conductivity.

In order to obtain realistic conductivity results it is often necessary to pass steam samples through an ion-exchange degasser (resin-bed) - this exchanges hydrogen ions for cations in the sample eliminating all basic dissolved gases. This method is not satisfactory for all installations eg. where samples contain acidic gases. However, the boiler supplier should include a facility to suitably treat steam samples to give accurate analyser results.

2.5 **Fuel Requirements**

- * 2.5.1 The purchaser will specify the pressure, temperature, viscosity and analysis at which each fuel is available at the battery limits. When these conditions require adjustment to suit the combustion characteristics of the burner, the vendor shall provide appropriate equipment.

- 2.5.2 All liquid fuels are to be burnt at a viscosity of 15 centistokes or less as measured at the burner tip. If the fuel provided is not already at the



correct temperature to achieve this viscosity then the vendor shall provide a fuel heating system with automatic control. The control system shall ensure that the viscosity does not exceed the agreed limit at any flowrate and over the range of possible supply temperatures which the purchaser will specify.

Note that it is generally cheaper and common practise to utilise temperature control rather than viscosity.

- 2.5.3 The vendor shall select, for agreement with the purchaser, the type, quality and quantity of atomising medium to be used to assist burning of any liquid fuel.

When steam is used the purchaser will ensure that the steam supply is dry at the battery limit.

2.6 Air Pre-Heat

- 2.6.1 Where site wide energy integration shows this to be advantageous the combustion air supply for the boiler should be pre-heated using steam at the lowest practicable temperature, as specified by the purchaser. The air should be heated to within 20 deg C of the steam temperature at the average boiler output. Average, minimum and maximum values for the inlet air temperature should be specified by the purchaser on the Data Sheet.

The use of steam for air pre-heat duty is preferred where appropriate to enable heat integration of the boiler with any process units and ultimately, if not initially, to permit this steam to be generated from 'below the pinch' process fluids.

Site specific factors may result in modified approaches, eg use of hot water streams, or even preclude against adoption of this feature.

Note that air preheat can marginally increase NOx emissions.

- 2.6.2 As an alternative to 2.6.1 consideration should be given to combustion air preheating by means of heat recovery from the exhaust gas and/or utilising auxiliary steam for normal or cold start duties.

2.7 Combustion

The amount of combustion air used in excess of stoichiometric needs shall not exceed the following (by volume, dry):-

- (a) 15% for units up to 50 t/h MCR
- (b) 10% for units up to 100 t/h MCR
- (c) 5% for units above 100 t/h MCR

2.8 Emissions to Atmosphere

*

For fired boilers the purchaser will specify the maximum gaseous emissions appropriate to the project. Gaseous emissions shall be measured and corrected to 3% oxygen by volume (dry).

This 3% requirement may vary dependent on local requirements

The following default values shall apply when no project details are defined :-

(a) Carbon Monoxide (CO)

A default maximum of 25 mg/m³.

(b) Oxides of Nitrogen (NO_x)

A default maximum of 300mg/m³ for gas firing and 450mg/m³ for oil firing plus the equivalent due to any fuel nitrogen.

(c) Particulates

The carbon content of any particulate emissions produced by the boiler shall not exceed 0.5% by weight of the fuel derived ash.

2.9 Chimney

*

2.9.1

For direct fired boilers, and where included in the vendor's scope of supply, the chimney shall be designed as follows. At the maximum boiler design load the chimney shall develop a net suction pressure which balances the pressure loss due to the flow of flue gas through it. The height and the design discharge velocity shall be specified by the purchaser to meet the project environmental requirements. As a minimum the design discharge velocity shall be not less than 14 m/s and the height shall be not less than 5 m above the highest permanent access point in the vicinity of the boiler or the FD fan suction, whichever is the higher. In the case of fuels with a sulphur content of more than 0.5% (by weight) the chimney shall be not less than 10m high.

The minimum discharge velocity is specified to minimise the possibility of cold air recirculation and problems with downwash. Balanced draught gives an economic design and may help contractually. Sulphurous fuels may require heights significantly greater than 10 m.

2.9.2.

A self supporting design is preferred in order to minimise structural steelwork.

2.10 Heat Sources

*

Where the boiler heat source is a hot fluid stream (which may be from a process or engine) then the purchaser will specify all necessary fluid property data. This would include the fluid mass flow rate, composition, temperature, dewpoint and dust burden. Physical details of the pipe/duct at the battery limit will also be defined by the client.

2.11 Heat Recovery

2.11.1 Requirements vary depending on the type of boiler and operating conditions.

Some designs may benefit from a separate feed water heater utilising LP steam.

2.11.2 For conventional fired boilers, ie those designed to burn only normal commercial grades of fuel, and any other type of boiler in which the heat source has a lesser thermal capacity than the economiser water flow, the economiser shall be rated to give the pinch point temperature stated in 2.11.4.

2.11.3 For boilers other than 2.11.2 above, the evaporator section shall be rated to give the pinch point temperature stated in 2.11.4.

2.11.4 The required pinch point temperature shall be determined according to the fuel quality as follows :

20 deg C for clean gas
25 deg C for distillate oil
30 deg C for light residual oil*
40 deg C for heavy residual oil*

* Also applicable to fuel gas with a particulate burden similar to the ash produced from the residual oil firing.

Fuel prices will effect decisions on the value of heat recovery and the pinch point temperature, which may require adjustment. The purchaser may wish to review the optimum value for a particular project by calling for alternative quotations at different pinch point temperatures. The long term fouling effects of certain fuels must also be taken into account.

2.11.5 The economiser outlet temperature shall be preferably no less than 10 deg C below the evaporation temperature (see 4.19.1).

2.11.6 The economiser inlet water temperature shall be at least 5 deg C above the dewpoint of the flue gas under all operating conditions. The feed water temperature will be given by the purchaser on the Data Sheet and the vendor will confirm that this margin applies in all cases.



Ideal economiser inlet conditions are considered to be either 5 deg C above the average flue gas dewpoint, or the deaerator outlet temperature, whichever is the higher.

2.12 Heat Loss from the Boiler Casing

*

The vendor shall specify the quantity of heat lost and the casing temperature. This loss shall be not more than 2% of the boiler heat input. The client should define appropriate penalties in case of non-compliance.

In the event that the casing temperature is found to be higher in service a penalty could be determined based on say two years of additional heat loss at the current price of fuel.

The vendor shall provide all necessary insulation for personnel protection.

2.13 Operation

2.13.1 The boiler shall be designed and equipped for fully automatic operation with remote manual controls in the control room. Start up and shut down shall utilise automatic sequence control with manual supervision and initiation from the control room of each step in the sequence. All instruments to enable the safe and economic operation of the boiler in both manual and automatic modes shall be provided.

2.13.2 Instruments to aid trouble shooting should be proposed by the vendor for client approval.

2.13.3 All instruments necessary to assess the performance of the boiler and to detect fouling shall be provided.

2.13.4 Waste heat boilers may be required to operate dry and the purchaser will indicate this as a special requirement on the Data Sheet. Dry running requires the boiler to be capable of accepting the maximum heat input and gas temperatures with fully drained water and steam tubing. Any limitations on operation in this mode shall be agreed with the purchaser.

2.14 Utility Consumption

The vendor shall advise the electrical power, steam, and other utility consumptions of the boiler and these shall be subject to guarantee.



2.15 Testing

The timing and duration of boiler performance tests shall be agreed between the purchaser and supplier. Ideally testing will be conducted immediately following commissioning, however, the timing should take account of both feedwater/condensate losses and steam consumer availability.

Recommended minimum testing and periods are as follows:-

- (a) Maximum Continuous Rating 8 hours
- (b) Peak or Overload Condition 2 hours
- (c) Normal Operating Load 8 hours
(or any specified test point eg. 80%)
- (d) Minimum Automatic Load Control 8 hours
- (e) Load change - load rejection and load acceptance of step changes.

Thermal efficiency calculations shall follow the [ASME Power Test Code](#) for Steam Generating Units PTC 4.1.

In multi-boiler installations all units shall be tested.

The purchaser should consider boiler testing requirements at an early stage of the project, often it is difficult to arrange the necessary consumer flexibility. Other problems can arise from excessive water wastage due to steam venting and establishing acceptance criteria for load changes - especially where the boiler vendor is not the feed pump supplier.

3. PROJECT REQUIREMENTS

3.1 Scope of Supply

3.1.1 The battery limits defining the minimum extent of supply would be generally as follows and apply to each steam pressure level:-

- (a) At the outlet of the main steam stop valve and including a non return valve.
- (b) At the boiler flue gas inlet to the chimney.

- (c) At the outlet of the continuous blowdown control valve downstream of the blowdown cooler and at the outlet of the manual control station for intermittent blowdown.
- (d) At the inlet to the feed water isolating valve upstream of, and including, the feed water control valve.
- (e) At the inlet to the desuperheater spray water isolating valve upstream of the spray water control valve.
- (f) At the inlet to the combustion air filter upstream of the FD fan.
- (g) At the inlet to the isolating valve upstream of each fuel control valve.

The fuel pressure, temperature, or other conditions may not be optimum for combustion and the vendor should be asked to confirm they are acceptable or advise recommendations for any additional equipment.

- (h) At the inlet to the isolating valve upstream of the atomising medium control valve.
- (i) At the boiler inlet connection of any waste heat source.
- (j) At the inlet to the isolating valve on the common supply to all sootblowers and at the outlet from the common steam condensate discharge.

3.1.2 The scope of supply shall include all supporting steelwork, integral electrical and control equipment and cabling and integral utility piping (compressed air, steam, nitrogen, etc.) from defined terminal points.

3.1.3 The scope of supply may be modified as necessary and the following additional plant could be included to suit project requirements :-

The chimney, boiler feed water pumps, feed water heater, fuel forwarding skid, ducting, silencers, bypass stack, isolating and control dampers, chemical dosing skid, sampling rack etc.

3.2 **Information**

The timely delivery of vendor information is important to ensure adherence to the project schedule. Typical requirements from the vendor would be expected at the times indicated as follows:-

3.2.1

With Tender

- (a) A list of all exceptions to the specification.
- (b) A list of the vendors proposals to improve operability, reliability or other aspect for the purchaser's consideration.
- (c) Ex works delivery schedule, manufacturing location, weight and transport time to site for all supply components.
- (d) An analysis and schedule for the site work to assemble the boiler and prepare it for service, ie. field erection sequence and procedure, estimated manhours and trades, site weld requirements, chemical cleaning operation, etc.
- (e) A proposal by the vendor to execute the site assembly or to provide site supervision for erection by others.
- (f) Details of performance guarantees.
- (g) Heat and mass balance for guarantee conditions.
- (h) Temperature and pressure in each section of the boiler, both on the water/steam side and the flue gas/heat source side.
- (i) Furnace average heat absorption rate.
- (j) Preliminary PFD.
- (k) Preliminary P&ID.
- (l) Preliminary general arrangement drawing of the boiler with cross sections to clarify the design concept and show sootblower locations.
- (m) Preliminary overall plant layout drawings.
- (n) Steam drum internal arrangement drawing.
- (o) Details, including number of coils, tube sizes, and material specifications, of all principal components e.g. superheater, economiser, etc.
- (p) List of all instruments, alarms, trips and control loops.
- (q) A list of all subcontracted equipment with prices for individual items which cost more than 5% of the contract price.

3.2.2 Post Contract

3.2.2.1 Within 5 Weeks

- (a) Fully detailed first issue PFD.
- (b) Heat and mass balances at 100, 75, 50, 25 and 12.5% MCR including any de-superheater spray water quantities and flue gas recirculation flows.

3.2.2.2 Within 10 Weeks

- (a) Boiler circulation calculations.
- (b) All pipe bore dimensions and pressure drop calculations.
- (c) Safety relief valve pressure settings.
- (d) Boiler feed water pump maximum discharge pressure calculated at the highest evaporation rate and the maximum boiler safety relief valve set pressure.
- (e) Chimney height, diameter, temperature drop and calculated pressure drop.
- (f) Combustion air and flue gas pressure drop calculations.
- (g) FD and ID fan maximum calculated discharge pressure.
- (h) Preliminary foundation loadings.

3.2.2.3 Within 15 Weeks

- (a) Final PFD.
- (b) Final P&ID.
- (c) Instrument ranges.
- (d) Control settings.
- (e) Alarm settings.
- (f) Trip settings.
- (g) All control valve specifications.



3.2.2.4 Within 20 Weeks

- (a) Preliminary control panel layout and size.
- (b) Final layout drawing.
- (c) Structural steelwork drawings.
- (d) Diagram showing anchor points and thermal expansion provisions.
- (e) Diagram showing point and distributed loads.
- (f) Burner management gate logic diagrams.
- (g) Final electrical diagrams.
- (h) Boiler general arrangement drawings.
- (i) Boiler pressure part calculations for insurance company review.
- (j) Boiler pressure part drawings.
- (k) Boiler non-pressure part drawings.
- (l) Physical details and conditions at all terminal points.
- (m) Final foundation loading information.

3.2.2.5 Within 25 Weeks

- (a) Final control panel layout and size.
- (b) Operating instructions (preliminary issue required four weeks before start up).
- (c) Maintenance instructions.
- (d) Commissioning instructions.
- (e) Spares required for pre-commissioning, commissioning and twelve months operation, individually priced.
- (f) A manual describing all spares required for normal operation, with prices.



4. DESIGN REQUIREMENTS

4.1 Anticipated Life Span

- 4.1.1 In general the boiler shall be designed and manufactured to have a life span without limit when operated and maintained in accordance with the vendor's instructions. The only possible exception to this shall be superheaters and reheaters, which may be designed for a minimum operational life of 100,000 hours without any tube or other pressure part replacement.

Increased design life of up to 250,000 hours may be justified dependent on the replacement cost of the superheater and its practicality. The actual life achieved will depend on service conditions and creep or fatigue may be limiting factors.

- 4.1.2 Boilers will generally be designed for continuous duty and capable of either fixed base load or load following control. Where necessary for application to two shifting or similar duties the boiler thermal stress analysis shall take full account of the additional fatigue impact.

4.2 Scheduled Inspection and Maintenance

The boiler, and any equipment on which it depends, shall be capable of operating for at least three years (38 months maximum) between scheduled inspections. The scheduled maintenance should not result in the boiler being out of service for more than one week. Any refractory materials used in the construction of the boiler should be designed to require minimum maintenance.

4.3 Reliability

The boiler and all equipment and software within the scope of supply shall be designed and selected to achieve the specified reliability.

The particular project requirements should be determined from studies of the specific application such that the boiler vendor is given a definite reliability target.

4.4 Design of Pressure Parts

- 4.4.1 The mechanical design of the pressure parts and boiler mountings (valves, gauges and safety devices) shall conform to the national code for the country in which it is to be installed and/or either [ASME Section I](#), [BS 1113](#) and [BS 759](#) Part 1, or appropriate ISO standards. The minimum mechanical design pressure shall be 20 barg.

- * 4.4.2 The boiler pressure parts, casings and ducts should be made of carbon steel which does not require any pre or post weld heat treatment for

thicknesses up to 20mm. Any cases where this is not feasible shall be reported in the quotation. Low ductility material shall not be used without prior approval of the client.

- 4.4.3 A corrosion allowance of at least 1mm shall be provided in the mechanical design of tubes up to 100mm OD and 1.5mm for larger diameters.
- 4.4.4 Drainable superheaters are preferred, however, pendant style superheaters with non-draining loops are permitted. All other pressure parts shall be drainable and appropriate provisions included.
- 4.4.5 Bifurcation of evaporator tubes shall be permissible only after thorough analysis of the boiler circulation and subject to prior agreement of the client.
- 4.4.6 The pressure parts should be configured so as to minimise the use of refractory.

4.5 Control and Instrumentation

- 4.5.1 The boiler shall be designed for normal operation without an operator in attendance. Control systems shall be provided for normal control of boiler functions. Protective systems shall be provided to guard against failure of the control systems and for the safe start-up and shutdown of burners.

The design of the control system, burner management system and protective systems shall be compatible with the safety and operational availability requirements.

Protective systems shall de-energise to trip. Key operated trip overrides with alarms on operation shall be provided for testing.

Protective systems should stand alone wherever possible eg. any measurement required for the burner management system should be provided directly and independently of the control system, avoiding the use of software links between the two systems. The use of software processing and serial links between systems is encouraged for information monitoring and cross checking purposes.

Transmitters are the preferred method of providing signals for inputs to control and shutdown systems, making maximum use of communications between systems to provide system monitoring, diagnostics and fault tolerance.

- 4.5.2 Protection Against Combustion Explosions

Combustion shall be controlled and protective devices shall be provided in accordance with an appropriate national/international code as agreed

with the purchaser. The British Gas Publication [IM/18](#) or [NFPA 85C](#) would be acceptable.

For oil burners [EN 230](#), [EN 226](#) and [BS 799](#) : Part 4 may be adopted as applicable.
For gas burners [BS 5885](#) : Part 1 may be adopted as applicable.

Protective systems shall be categorised using BP Group [RP 30-6](#), assessing demand rates on the protective system, the exposure of personnel and carrying out a reliability assessment on the proposed equipment with the necessary proof test interval. The reliability assessment for safety, together with the required operational availability of the boiler will determine the numbers and configuration of the protective equipment eg. the selection of 1 out of 2, 2oo2 or 2oo3 monitoring for flame scanners or low pressure trips and single or double isolations for the outputs.

The critical aspects of operation, in preventing combustion explosions, are the correct purging of the boiler followed by lighting and detection of the first pilot and main burner. On detection of loss of flame or other burner shutdown condition the fuel valves should close with Class IV shut-off and should not be reset until the correct operating sequence has been established ie. either burner re-start or boiler purge and re-start.

The design of the boiler should preferably allow on line testing of burner safety systems eg. flame scanners and low/high pressure gas shutdown. The preferred method of testing on multiple burner boilers, is to manually isolate the fuel supply, ensuring correct operation of protective devices. For flame scanners this will ensure that the scanner is correctly monitoring a specific flame, detects an actual loss of combustion and isolates the fuel supply, with tight shut off. The testing of flame scanners by operations personnel, as part of routine operation, using this method is encouraged.

On single burner boilers, testing of the protective systems will require shutdown of the boiler. The frequency at which this occurs should be determined in the reliability analysis. The protective systems inputs on a single burner boiler will generally be duplicated allowing testing of individual shutdown inputs, however the method and frequency of testing should be developed to ensure that representative tests are being carried out. For example, obscuration of a flame scanner and checking for zero output is not a representative test for loss of combustion.

The intention in purchasing controls and instrumentation is to utilise vendor standard systems, which provide the required level of hazard reduction and have a residual level which is acceptable to the client. The hazard reduction can be provided by a combination of vendor systems, additional systems providing hazard reduction as specified by BP and safe working systems such as operating procedures, control of over-rides and work permits. Care should be taken in evaluating the contribution of control systems to overall hazard reduction and the credit assumed for control systems should not exceed a factor of 10, otherwise it should be considered to be a safety system.

4.5.3 Protection Against Overheating Failures Due to Low Water Level

Each steam drum shall be provided with specific devices to protect the boiler in case of failure of the level control system. The protective



system shall comply with the appropriate national/international Codes of Practice and legislation as agreed with the purchaser.

Protective systems shall be categorised using BP Group RP 30-6, assessing demand rates on the protective system, the exposure of personnel and carrying out a reliability assessment on the proposed equipment with the necessary proof test interval.

Loss of level can lead to dryout and failure of evaporator tubing. Whilst tube failures within boilers may be contained within the boiler casing, there have been examples of loss of containment with serious external damage to facilities and a corresponding hazard to personnel.

- 4.5.4 Protection against high steam drum level should be provided except where downstream equipment can tolerate water carryover.

4.6 Furnace Design

- 4.6.1 The furnace shall be sized in order that the peak heat flux does not exceed the following values with any fuel or combination of fuels being fired. The peak heat flux shall be interpreted as the maximum spot value of heat absorbed at any point on the inside tube surface, based on the flat projected area of the tube panel in question.

- 4.6.2 The furnace average heat absorption rate should be determined from the emissivity values given in 4.6.6 and be based on the flat projected area of the whole furnace and referred to the inside tube surface. Where the fuel categories are less well defined, emissivities should be agreed with the client.

It is very important to get a realistic assessment of the furnace heat absorption since this also determines the gas exit temperature, which in turn sets the design of any superheater and downstream convection banks. Manufacturers generally utilise proprietary data and calculation procedures which may require some interpretation of the quoted emissivity values.

- 4.6.3 Up to a steam pressure of 60 bar the boiler shall have a peak heat flux not exceeding 300 kW/m^2 at any point in the boiler, unless higher quality water (zero solids) is supplied as specified in BS 2486 for boilers at 80 bar. In the event that the water quality is not specified it shall be assumed that the 300 kW/m^2 limit applies.
- 4.6.4 With pumped water circulation the peak heat flux limit may be increased to 450 kW/m^2 . Where partial pumped circulation is adopted this limit is only permissible in those parts which are pumped.

Note that the 450 kW/m^2 level was discussed in committee during preparation of BS 2486 but not published.

4.6.5 For an ideal furnace shape and burner arrangement giving a well balanced heat distribution, the furnace should be designed for a ratio of peak to average heat flux as given below according to fuel type. The furnace size shall therefore be designed to ensure that the selected average heat flux does not cause the peak heat flux to exceed the specified values.

4.6.6 The required RATIO of peak to average heat flux and EMISSIVITY values shall be as follows.

FUEL	RATIO	EMISSIVITY
Heavy residual oil	1.6	0.90
Light residual oil	1.5	0.85
Distillate oil and C ₃ + gases	1.4	0.75
C ₁ and C ₂ gases	1.3	0.70

4.6.7 Where the furnace shape and the burner positioning results in a heat flux profile with high peak values in local areas or an unusually skewed distribution, then the furnace shall be analysed on the basis of individual sections having reasonably similar heat flux levels.

4.6.8 The floor tubes of all furnaces having a slope of less than 15 degrees to the horizontal shall be insulated with refractory tiles.

This is required in order to minimise heat transfer to such tubes and hence prevent steam blanketing and flow stagnation.

4.6.9 The minimum distance between the centre of a burner and any furnace containment surface shall be 1.0m for burners below 20 MW heat release rating. Where there is more than one burner the minimum distance between burners shall be 1.5m. These minimum distances shall be increased in proportion to the square root of the heat liberation for burner sizes above 20MW. The burner air register pressure loss should be preferably not less than 15 mbar and shall not be less than the minimum stipulated in BP Group [GS 156-1](#).

4.6.10 Furnaces shall be made from gas tight, fully welded, evaporator panels built up from longitudinal fin tube sections. Tangent tubes with seal welding are not permitted for furnace construction.

4.6.11 An access door, having a minimum dimension of 600 mm, shall be provided to permit inspection and in situ repair of the burners.

4.6.12 Observation ports shall be provided to enable the following parts of the flame to be observed: the flame root, the flame tail and the proximity of the widest part of the flame to any wall, roof or floor. The observation ports shall be air purged to keep them free of deposits.

- 4.6.13 Burner walls are preferred as fully water cooled surfaces except when bottom fired.

4.7 Steam and Water Separation

At each pressure level a suitable combination of the following design features will be provided for separating the steam and water phases, selected as necessary to meet the specified steam quality.

4.7.1 Primary Separation

Centrifugal separators shall be provided for forced circulation boilers and are preferred for natural circulation boilers. For natural circulation boilers which have insufficient pressure drop available an inertial separator is acceptable.

4.7.2 Secondary Separation

The steam drum shall be sized to give sufficient free area between the primary and tertiary separation to allow discrete water droplets to fall by gravity from the steam as it leaves the water surface.

- 4.7.3 The vapour speed, both horizontally and vertically shall not exceed 0.5 m/s and preferably be less than 0.3m/s. For steam drum operating pressures up to 40 bar, the ratio of the vapour volumetric flow rate to the available steam space shall not exceed 700m³/h per m³ of space. Above 40 bar the permissible ratio shall be reduced in proportion to the pressure, e.g. 350m³/h per m³ of space at a steam pressure of 80 bar.

- 4.7.4 The determination of vapour speed and available steam space shall relate to the water level at the high level alarm setting. Spaces occupied by the separation equipment and stagnant areas at the drum ends shall be discounted.

4.7.5 Tertiary Separation

This shall consist of demister pads with a sufficiently low steam inlet velocity to allow separated water droplets to fall by gravity against the flow of the incoming steam. The pads shall be not less than 300 mm above the water level at the high level trip setting.

4.8 Natural Circulation

All evaporator tubing sections having natural circulation shall be designed according to the following criteria.

4.8.1 No downcomer shall generate steam. Downcomers shall be either (a) unheated or (b) if heated, the inlet water shall be sufficiently sub-cooled to prevent boiling at any point.

4.8.2 Downcomers shall absorb between 10 and 25% of the available head.

A minimum pressure drop is required through the downcomers in order to avoid potential instability in the risers. The upper limit is set to prevent the use of too few downcomers which might adversely effect circulation.

4.8.3 The downcomer inlet nozzles shall avoid zones where the proximity of riser discharge nozzles can induce carry-under of steam. Division plates and/or boxes shall be used as required to create a physical barrier to carry-under.

4.8.4 The maximum steam by volume in any riser shall not exceed 55%.

4.8.5 For circulation design, the evaporator circuits should be grouped according to similarity of heat absorption, diameter, length and configuration. The boiler shall be divided into not less than 10 groups. The riser heat absorption shall be characterised along the length of the tube if it varies by more than +/- 15%.

4.8.6 The circulation calculations shall show the net head developed by each group of risers at various water flow rates. The summated curve for all the riser groups and the friction head of the downcomers shall also be presented to identify the operating condition. The maximum percentage steam in each group of risers shall be identified along with the proportion of head used by the downcomers.

4.8.7 Boilers which utilise control of fuel firing to maintain steam pressure shall limit the rate of increase in firing rate to 25% of the maximum firing rate per minute.

At periods of rapid load increase it is important to ensure adequate cooling of the furnace tubing, which can suffer from excessive local steam generation, causing blanketing of the tube and flow instability. The level set is judgemental and it may be possible to increase the firing rate if an adequate steady state analysis has been performed to the satisfaction of the purchaser's professional engineer.

4.9 Forced Circulation

All evaporator tubing having forced circulation shall be designed according to the following criteria. The provisions of 4.8.3 also apply to prevent steam carry-under.

- 4.9.1 Either 2 x 100% or 3 x 50% fixed speed pumps shall be provided for circulation duty. Automatic initiation of the spare pump(s) shall be provided to cover for duty pump failure. Standby start initiation shall be from loss of electrical supply and pump speed - both being determinants of duty pump failure.

The boiler vendor shall consider the steam drum sizing in conjunction with the boiler feed pump arrangements and make provision for the automatic start-up of a standby pump, in the event of a duty pump failure, without interruption of boiler operation.

- 4.9.2 Where the boiler has some evaporator sections with natural circulation, the forced circulation pumps shall take suction remote from the feed water supply nozzles.

- 4.9.3 The minimum water speed on entry to each riser tube should be 0.3 m/s (1.0 ft/s). The overall pressure drop through the tubes should not be less than 3.5 bar (50 psi). Orifices installed on entry to each riser tube should provide a minimum pressure drop of 0.35 bar (5 psi).

- 4.9.4 The layout of the flue gas duct and the tube orientation should be designed to ensure uniform heat input to each tube circuit.

4.10 Forced Draught Burners

- 4.10.1 Forced draught (register) burners shall be in accordance with BP Group [GS 156-1](#). A test is recommended on a sample of any burner type which has not been previously demonstrated satisfactorily to the client.

Note that BP Oil carries out tests on commercial burners as required for the BP Group and third party projects. Advice should be sought from the Custodian on current experience and any need for testing.

- 4.10.2 Each burner shall be supplied with flame failure detection equipment of the self checking type.

The numbers and configuration of flame scanners will be determined by the protective system Categorisation reliability assessment and the operational availability of the boiler.

- 4.10.3 Any oil gun shall be located at the centre of the swirler. Gas guns may comprise of a number of gas 'spuds' close to the periphery of the swirler, which would suit dual fuel firing. Alternatively a central gas gun may be acceptable where a single fuel is required.

A centre gas gun may offer better turndown.

- 4.10.4 For igniting the main flame, each burner shall be fitted with an interruptible pilot burner which has a dedicated electrical ignitor. The

pilot burner will be shut down after ignition of the main flame has been proved. Where waste fuels are used with a possible large variation in calorific value it is permissible to use continuously ignited pilots in line with BP Group [GS156-1](#). The pilot flame shall be monitored by a flame detection rod. The capacity of the pilot burner shall be not less than 0.1 MW. The pilot flame shall be visible though the burner.

4.11 Other Burners

4.11.1 Burners for in-duct applications shall be subject to review of actual operating experience in similar service elsewhere. The vendor shall provide details of current experience for discussion and agreement with the purchaser.

4.11.2 For waste heat recovery boilers provided with supplementary firing the gas pressure drop across the burners should typically be in the range 1.5 - 4.0 mbar.

4.12 Fuel Systems

4.12.1 Fuel/air ratio control shall be provided, with oxygen (in flue gas) trim control. If two burners are required then a separate fuel/air ratio control shall be fitted on each burner.

The trim control should be designed to minimise excess air in order to achieve the best thermal efficiency when the boiler is operating within the specified range of turndown.

4.12.2 The combustion air supply shall be increased ahead of the fuel on increasing load. The fuel supply shall be reduced ahead of the combustion air on decreasing load.

4.12.3 The purchaser may require an on-line CO analyser (see Data Sheet).

The CO analyser may be used to back up the oxygen analyser in locating the best operating efficiency at any time without exceeding the flue gas emission limits and without significant boiler fouling due to unburnt fuel.

4.12.4 For gases which are expected to display a significant variation in composition during operation of the boiler, measurement of gas density should be provided. This equipment may be outside of the boiler scope, in which case appropriate details must be provided by the purchaser.

The design pressure of fuel systems should generally be not less than 20 barg and sufficient to avoid the need for overpressure protection.

4.12.5 All liquid fuel lines should be supplied with a duplex filter with a mesh size of 0.25mm for heavy residual oil and 0.18 mm for distillate oil. A

differential pressure gauge shall be provided to determine the pressure drop across the filter.

4.12.6 The pilot gas fuel system shall have 125 micron duplex filters with downstream piping made of stainless steel.

4.12.7 A knock-out pot shall be provided on gaseous fuel supplies, close to the burners. Offtakes for individual burners shall be from the top of the header, downstream of the knock-out pot.

These features are to avoid condensate carry over to the burners. In addition trace heating may be necessary.

4.12.8 All fuel isolation valves shall be of the ball type. The design of attachments and valve configurations must minimise the potential for fuel spillage at the boiler front.

4.12.9 Local to the boiler a lockable cupboard would normally be provided to contain the spare burners, parts, tools and cleaning equipment. A bench should also be provided to facilitate dismantling, cleaning and re-assembly of burners removed from the boiler.

4.12.10 Fuel pipework shall be provided with suitably blanked connections to allow attachment of temporary piping for purging. These connections shall be located close to, and downstream of, the shut off valves.

4.12.11 Fuel oil and gas pipework shall be trace heated with steam or electrical systems as agreed with the purchaser in accordance with site ambient or design conditions.

4.12.12 Atomising steam lines shall be lagged separately from the fuel lines.

4.12.13 The atomising steam pressure shall be controlled to suit the selected burner design.

4.12.14 All fuel supply piping systems shall incorporate easily accessible manually operated isolation valves remote from the boiler. These valves may be supplied by others.

There are case histories of boiler fires continuing for longer than necessary because no isolation valves were available to shut down fuel lines.

4.12.15 The arrangement of the fuel supply to the burner system shall be determined from the operational availability and turndown requirements for the boiler.

Typically, this may be 2 x 100% or 3 x 50% fuel pressure regulation streams to enable maintenance of equipment. The steam flow turndown of the boiler may require different size streams or split range arrangements for control valves.

4.13 FD Fan and Air System

4.13.1 The combustion air flow shall be measured using a venturi meter rated to give a signal of not less than 100mm wg.

4.13.2 For outdoor units the air intake shall be at least 3 m above ground level and be provided with a rain/snow hood and trash screen.

4.13.3 Where more than one fan is used the type of fan selected shall ensure stable operation with the other fans in operation.

Fan driver selection whether electric motor with hydraulic coupling, variable speed electric motor or steam turbine, shall consider operational security, the site electrical power/steam balance and requirements for "black" start. Air flow should be controlled by variation of the driver speed; where necessary additional control range can be provided by adjustable inlet guide vanes.

Where parallel operation of fans is intended the control system should ensure equal air flow loading and avoid hunting problems.

If necessary for "black" start one fan (or pair of fans in balanced draught installations) may be driven by both an electric motor (for initial start) and steam turbine (for normal use) with a clutch type drive disengaging facility.

4.13.4 Air ducts shall be externally stiffened. No internal stiffeners shall be used unless these are streamlined to the air flow. The design air speed shall not exceed 15 m/s. Guide vanes should be fitted inside air ducts and the windbox where necessary to ensure good air flow distribution. Access doors shall be provided to enable inspection of all ducting and for viewing any air heater.

4.14 Flue Gas System and ID Fan

4.14.1 Penetrations of the flue gas containment system shall be minimised. The system shall be subjected to a smoke test or equivalent to identify any leaks which shall be rectified by the vendor.

4.14.2 Stiffening of flue gas ducting shall be either external or be streamlined to the flue gas flow. Expansion joints shall be provided at both the suction and discharge of any ID fan to cater for differential thermal growth and to prevent the transmission of vibration.

4.14.3 Access doors, with a minimum dimension of 600 mm, shall be provided to enable inspection of all ductwork and all heat transfer tube banks.

4.14.4 All ducting shall be heat insulated where necessary for personal protection and as agreed with the purchaser to conserve energy.

4.14.5 Duct anchor points, sliding supports and expansion joints shall be clearly marked on relevant drawings.

4.15 Drums and Headers

4.15.1 The minimum internal diameter shall be 900mm for steam drums and 600mm for water drums. Steam and water drums shall be fitted with manholes having one dimension of at least 450mm. Steam and water drums shall be not less than 20mm thick.

4.15.2 Headers shall not be less than 150mm internal diameter and 10mm thick. Inspection nipples shall be provided on every header.

4.15.3 Steam drums shall be provided with three element control which shall maintain the operating water level within ± 50 mm of normal under steady state conditions. During load changes of up to 25% MCR per minute, the water level shall be controlled to within ± 100 mm of normal.

Load acceptance and rejection tests may be developed depending on the boiler application.

4.15.4 The drum shall be fitted with alarms set at ± 150 mm, or greater, of the normal water level. High and low level water trips shall be provided at not less than 50mm from the alarm settings.

In exceptional circumstances high level trips may be deleted (see 4.5.4).

4.15.5 No steam drum downcomer nozzle shall be covered by less than 100 mm of water at the low water level trip setting. No pump suction nozzle shall be covered by less than 150 mm of water at the low water level trip setting. Where riser nozzles are not boxed to the primary separator, they shall be covered by at least 225 mm of water at the low water trip setting.

4.15.6 The feed water shall be uniformly distributed along the length of the drum.

4.15.7 The steam drum shall be fitted with boiler level indicating equipment in accordance with appropriate Codes of Practice. The minimum requirements comprise one level indicator in the control room and one indicator at a local panel, preferably adjacent to the firing and feed water controls. For boilers up to 40bar operating pressure a level gauge glass should also be provided on the steam drum. Hydrastep equipment is acceptable.

4.15.8 Blowdown and chemical injection piping shall be provided within the steam drum.

4.15.9 Samples of all header pipe materials shall be supplied to the purchaser suitably identified to facilitate future boiler life extension investigations.

4.16 Desuperheaters

4.16.1 Surface cooling steam desuperheaters shall not be used inside any steam or water drum unless approved by the purchaser.

4.16.2 For control of steam temperatures in excess of 400°C an interstage desuperheater shall be provided. At lower temperatures the desuperheater may be installed downstream of the final superheater stage.

Alloy steels are generally required for service above 400°C and hence it is cost effective at that point to introduce an interstage desuperheater to minimise final stage metal temperatures.

4.16.3 Spray water for desuperheaters shall be either demineralised or high quality steam condensate.

4.16.4 Desuperheater spray water may be supplied from the main boiler feed pumps or from separate spray water pumps. In either case consideration shall be given to diversification of pump drivers and requirements for immediate automatic start. A minimum of one 100% duty steam turbine driven pump and one 100% duty electric motor driven pump should be provided.

4.16.5 In the event of a desuperheater failure, eg loss of spray water, the downstream equipment shall be designed to avoid short term damage.

The material life should be calculated for downstream equipment in this condition to confirm that the design is acceptable. Note that Swedish regulations require duplicate spray systems.

4.16.6 Desuperheaters shall comply with BP Group [GS 156-6](#).

4.17 Convection Tube Banks

4.17.1 Flue gas baffles shall not normally be acceptable. Where they are agreed to be necessary, they should be constructed using evaporator tubes wherever practicable.

Baffles have proved to be a major problem in boiler maintenance.

4.17.2 Tube Replacement

Where possible the tube bank design should permit replacement of damaged tubes with the minimal loss of other tubes and with the shortest possible downtime.

This will not be practicable for current D-type package boiler designs.

4.17.3 Tube Configuration

For firing of residual fuel oils, or dirty gas fuels, or for unfired boilers with flue gases having a similar level of particulates (eg cat cracker gas), an in-line tube configuration and soot blowers shall be used.

4.17.4 Radial Fin Tubes

4.17.4.1 Convection bank tubing with radial fins shall have carbon steel fin material with a carbon content not exceeding 0.27%. The fin tip temperature shall not exceed 425°C. The fins shall be attached to the base tube by a continuous weld, or overlapping intermittent weld.

The carbon limit is set to avoid pre- or post-weld heat treatment. The temperature limit is set to minimise loss by oxidation.

4.17.4.2 Finned tube used in evaporator duty shall have a heat flux of less than 300 kW/m² as defined in section 4.6. Fins shall be vertically aligned, ie horizontal tubes, except in clean flue gas service which preferably should be vertically aligned but may be horizontally aligned. In this context 'clean' means negligible particulates as from natural gas firing.

4.17.4.3 Fin dimensions shall be as follows:-

(a) for residual oil fuels or flue gases with equivalent particulates :

Minimum gap between fins	10.0mm
Minimum fin thickness	2.5mm

(b) for distillate oil fuels or flue gases with equivalent particulates :

Minimum gap between fins	5.0mm
Minimum fin thickness	1.5mm

(c) for natural gas fuels or flue gases with negligible particulates :

Minimum gap between fins	3.0mm
Minimum fin thickness	1.2mm

The minimum gap values are set to facilitate cleaning, where necessary by steam blowers. The minimum fin thickness values are set to give mechanical strength and allowances for erosion damage.

4.18 Superheaters/Reheaters

- 4.18.1 Where reasonably possible all elements should be self draining.
- 4.18.2 Radiant surface is not preferred. Where appropriate any incident luminous radiation should be screened by row(s) of evaporator tubes. Where unavoidable, radiant superheater tubes shall be fed with saturated steam.
- 4.18.3 The performance prediction of superheaters and reheaters generally requires a margin to cover design uncertainties. For each tube bank the vendor shall indicate the calculated average exit steam temperature which would be expected if the overall design heat transfer rate was increased by 10%.
- 4.18.4 Additional uncertainties exist in the flow distribution between elements. The vendor shall state what allowance is included for this in terms of the maximum and minimum deviation expected from the average steam exit temperature.
- It would be expected that a minimum of $\pm 10\%$ be allowed in the overall heat transfer rate to cover this effect.*
- 4.18.5 The allowances in 4.18.3 and 4.18.4 shall both be applied in calculating metal temperatures and selecting appropriate materials.
- 4.18.6 The steam flow pressure drop through each tube bank shall not be less than 1.0 bar before the application of any design margins.
- 4.18.7 Hangers and spacers generally shall not be used. If unavoidable, hangers and suspension fittings shall be cooled wherever possible and shall have a life of at least 40,000 hours. They shall be fully accessible to permit future replacement.
- 4.18.8 The design shall include provision for steam flow to be vented to atmosphere during boiler start up in order to prevent overheating. Steam venting shall be to a suitable safe location above the boiler structure and through a separate silencer, with provision for expansion and condensate drainage.

The supplier shall also detail how much steam venting is necessary to avoid overheating the superheater, eg. 25-30% of MCR. In Class 900 and over double isolation valves shall be provided upstream of the start-up vent control valve to permit on line maintenance.

4.19 Economiser

4.19.1 Preferably economisers should not be designed to generate steam.

Steaming economisers are not preferred as two phase flow can lead to poor flow distribution. If a steaming economiser is proposed the supplier shall demonstrate a successful proven design with stable flow under all conditions.

4.19.2 Economiser tubes shall be aligned in the flue gas duct to achieve a uniform flue gas flow across the parallel water flow paths.

4.19.3 The minimum water velocity in each tube element shall not be less than:-

- (a) 1 m/s for upward water flow,
- (b) 2 m/s for horizontal water flow,
- (c) 3 m/s for downward water flow.

Higher velocities will be necessary in any case of local steam generation in order to avoid hydrodynamic instability.

4.19.4 Economiser pressure parts shall not be made from cast iron. Tube return bends shall be all welded - flanged construction is not permitted.

4.19.5 Welded joints shall be restricted to the minimum necessary for construction purposes and shall be fully accessible to permit future site maintenance and site welding procedures.

4.20 Boiler Cleaning

4.20.1 General

When the boiler is taken out of service for scheduled maintenance both the inside and outside tube surfaces will be inspected for fouling and corrosion. The vendor's design shall enable this to be readily achieved.

4.20.2 Flue Gas Side

4.20.2.1 Boilers fired with residual oil or dirty fuel gas, and those utilising equivalent waste streams, shall be provided with appropriate on-line cleaning equipment, e.g. steam driven soot blowers and/or sonic blowers. The vendor will specify the blowing frequency expected in order to achieve the vendor's performance guarantees.

Note that a friable ash is necessary to justify soot blowing and hence it is generally not practicable for high temperature surfaces, eg superheaters.

- 4.20.2.2 Steam soot blowers should be designed to clean no more than three tubes upstream or four tubes downstream of the soot blower location.
- 4.20.2.3 Efficient steam trapping shall be provided to ensure that the supply to any blower is free of condensate. It shall not be possible to shut down the steam supply to any retractable blower until it is fully retracted. Retractable blowers shall be provided with both manual and power operation.
- 4.20.2.4 Groups of blowers shall have sequence control with indication of each stage in the sequence.
- 4.20.2.5 Wall boxes, lances and nozzles shall be air sealed.
- 4.20.2.6 The vendor will specify the required auxiliary steam and/or electricity consumption.
- 4.20.2.7 Sonic blowers shall be of the low frequency type.
- The use of regular (every few minutes) sonic blowing can be beneficial in limiting the maximum particulate emission level.*
- 4.20.2.8 Off-line water washing facilities shall be supplied.
- 4.20.3 Water Side
- 4.20.3.1 The boiler should be given an alkaline boil out when first commissioned, with subsequent acid cleaning at an operating pressure above 60 bar. The boiler design should include suitably positioned nozzles to permit subsequent chemical cleaning as necessary to restore the internal surfaces following any fouling or corrosion being found in service.
- 4.20.3.2 Dead spaces shall be eliminated.

4.21 Combustion Air Preheater

- 4.21.1 Any steam/air heater should have a minimum mechanical design pressure of 20 bar, be of all welded construction, and have a corrosion allowance of at least 1.5mm. It shall be constructed of steel tubes with welded steel fins of sufficient strength to prevent deformation during water washing.
- 4.21.2 The air preheater shall be located to give the most uniform flow to the burners and shall have an air side pressure drop of at least 25 mm wg at MCR. Location within the burner windbox should be considered.

- 4.21.3 The air preheater shall be designed to enable off-load water washing.

4.22 Boiler Cladding

The external insulation of the boiler shall be protected by a weatherproof non-combustible metal cladding not less than 1.0 mm thick.

4.23 Boiler Support Structure

Structural steelwork should be minimised by placing equipment such as fans at ground level wherever practicable.

Where a boiler uses liquid fuel or is located within a fire-exposed envelope (as defined by [API 2218](#)) fireproofing, with a two hour rating, should be applied to the main structure in accordance with [API 2218](#) and BP Group [RP 24-1](#).

4.24 Platforms, Stairways and Ladders

- 4.24.1 Stairways and platforms for easy access shall be provided to all locations at which an operator may need to attend for start-up, shut-down, oil gun changes, peep-hole observation, trip testing, etc. Ladders shall only be provided as a means of emergency escape from a platform.

- 4.24.2 Platforms shall be interconnected to facilitate operator patrol and to provide more than one means of escape. Similarly interconnection shall be provided between platforms of adjacent boilers and, where beneficial to operations, other adjacent plant eg. deaerator structure.

Interconnection at the local control or monitoring level, usually the lowest burner level, and also at the boiler drum level is recommended.

- 4.24.3 Where access for mobile lifting equipment is impracticable permanent lifting davits shall be installed to facilitate maintenance. Particular attention is required to ensure that all safety valves can be removed easily for routine inspection.

4.25 Valves

- 4.25.1 All valves shall be made of steel and no cast iron shall be used. Each valve shall be provided with a metal tag stating it's duty and identification number. Above DN 100, steam and feed water isolation valves shall be parallel slide type. All other valves shall be back seating with rising spindle.

- 4.25.2 The vendor shall provide double isolation from the steam main, with a block valve, screw-down non-return valve, and a drain valve as the minimum. The vendor shall also provide double isolation at all drain and blowdown lines connected to the pressure parts and at any point on common systems where isolation for maintenance may be required whilst the remaining plant is in service.

In double isolation service, the block valve closest to the boiler shall be a globe valve to permit flow control.

- 4.25.3 In sizes DN 150 and above, the boiler steam isolating valve shall be motorised and provided with a by-pass for pressure equalisation. The bypass valve should also be motorised where remote boiler start and stop is specified.

- 4.25.4 Safety relief valves shall be complete with vent and drain piping, expansion chambers and exhaust mufflers. Safety relief valve drains shall be open ended, not connected to any collection system, nor present a hazard to personnel.

Manifolding of safety valve exhaust pipes, blowdown drum vents, etc. into a common muffler or silencer is not permitted.

4.26 Dampers

- 4.26.1 For boilers connected to a common duct or shared flue gas stack, isolating plates shall be provided. The plates should be designed to operate in the vertical plane, moving downward to isolate. Locking facilities should be provided for both the full open and full shut positions.

- 4.26.2 For other duties where isolation and modulation are required at different times the damper provided shall incorporate an air pressurised interspace so that any leakage is that of air from the interspace.

- 4.26.3 Damper material shall be selected according to the design operating temperature as follows :-

- (a) carbon steel for up to 426 deg C,
- (b) Corten A for 426 to 538 deg C,
- (c) 18/8 stainless steel above 538 deg C.

Dampers shall be driven either by an electric motor or air motor and shall have both local and remote position indicators.

- 4.26.4 Special consideration shall be given to equipment selection appropriate to high temperature and dust burden for cat cracker or similar applications.

4.27 Electrical Equipment

- 4.27.1 Except for fuel systems which are required to Zone 2 rating, all electrical equipment shall be of normal industrial standard suitable for non-hazardous areas.

- 4.27.2 Electrical cables shall be routed to avoid areas where there is a risk of fire or mechanical damage. Where high risk routes are unavoidable, fire resistant cables shall be used.



Boiler Type - Direct Fired / Supplementary Fired / Waste Heat / Unfired / Single Pressure / Multiple Pressure

	1	2	3
Steam Pressure (bar (ga))			
Steam Temperature (degC) (± 5 deg C normal; ± 10 deg C transient)			
Steam Flow at MCR (t/h)			
Average Steam Flow (t/h)*			
Min Steam Flow under Auto Control (%MCR)*			
Min Steam Flow under Manual Control (%MCR)*			
Min Steam Flow for Temperature Control (%MCR)*			
Min Steam Flow for Excess Air Control (%MCR)*			
Steam Quality - Silica (mg/l)* - Total Solids (mg/l)*			
Blowdown Rate (vendor to advise)			

Reliability Details

Special Requirements, e.g. dry running, cyclic duty, remote start and stop required

Design combustion excess air level *

Emission Limits

- CO *
- NO_x *
- particulates *

On-line CO Analyser required

YES/NO

Air Preheat (ref 2.6)

Lowest Practicable Steam Conditions

- pressure (bar (ga))
- temperature (deg C)

Inlet Air Temperature (deg C)

- minimum
- average
- maximum

Economiser (ref 2.11)

Feed water Inlet Temperature (deg C)

* for default values see text

DATA SHEET - OUTLINE SPECIFICATION



DEFINITIONS AND ABBREVIATIONS

Definitions

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

bar : Except when referring to a pressure differential, the unit is stated either as gauge pressure, bar (ga), or absolute pressure, bar (abs). Gauge pressure is measured from standard atmospheric pressure of 1.01325 bar.

Abbreviations

API	American Petroleum Institute
ASTM	American Society for the Testing of Materials
CO	Carbon monoxide
DN	Nominal diameter (millimetres)
FD	Forced Draught
ISO	International Organisation for Standardisation
ID	Induced Draught (Fan) or Internal Diameter (Pipe)
LP	Low Pressure
MCR	Maximum continuous rating
mg/l	milligram per litre
MW	megawatt
NFPA	National Fire Protection Association
NO _x	Oxides of nitrogen
OD	Outside Diameter
PFD	Process Flow Diagram
P&ID	Piping and Instrumentation Diagram
wg	water gauge

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.

European

- | | |
|--|--|
| EN 230 | Monobloc oil burners - Safety, control and regulation devices and safety times. |
| EN 226 (BS 799 Part 8) | Atomizing oil burners - Connecting dimensions between burners and heat generators. |

British Standards

- | | |
|-------------------------|---|
| BS 759 | Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers. Part 1: Specification for valves, mountings and fittings. |
| BS 799 | <i>Oil burning equipment. Part 4 : Specification for atomizing burners (other than monobloc type) together with associated equipment for single burner and multi burner installations.</i> |
| BS 1113 | Specification for Design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers). |
| BS 2486 | Recommendations for Treatment of water for land boilers. |
| BS 5885 | <i>Automatic gas burners. Part 1 : Specification for burners with input rating 60 kW and above.</i> |

American

- | | |
|------------------------------|---|
| API 2218 | Fire Proofing Practices in Petroleum and Petrochemical Processing Plants. |
| ASME PTC 4.1 | Power Test Code for Steam Generating Units |



ASME Section I

Boiler and Pressure Vessel Code, Section I, Rules for Construction of Power Boilers.

NFPA 85C

Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces.

BP Group Documents

BP Group [RP 24-1](#)

Fire Protection - Onshore

BP Group [RP 30-6](#)

Design Philosophy for Protective Instrument Systems

BP Group [GS 156-1](#)

Forced draught burners for water tube land boilers.
(replaces BP Std 108)

BP Group [GS 156-6](#)

Steam pressure reducing and desuperheating systems.
(replaces BP Std 215)

EEMUA and other Documents

British Gas

Publication IM/18 : Code of practice for the use of gas in low temperature plant.

