

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

TECHNICAL SPECIFICATION

WATER-TUBE BOILERS

PTS 30.75.10.30

JANUARY 2010



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This revision of **PTS 30.75.10.30 – WATER-TUBE BOILERS (January 2010, Revision 1)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this **PTS 30.75.10.30 (September 2002)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	5
1.5	CHANGES SINCE PREVIOUS EDITION	5
2.	DESIGN AND ENGINEERING	6
2.1	GENERAL	6
2.2	<i>PRESSURE PARTS</i>	6
2.3	AIR AND FLUE GAS SYSTEM	13
2.4	FUEL SYSTEM	15
2.5	BOILER MOUNTINGS	18
2.6	MATERIALS, FABRICATION AND STRUCTURES	21
2.7	PRESERVATION AND INITIAL PREPARATION	23
2.8	ELECTRICAL INSTALLATIONS	24
2.9	CHEMICAL DOSING INSTALLATION	24
2.10	NOISE LIMITATIONS	24
3.	INSTRUMENTATION FOR IPF AND CONTROL	26
4.	QUALITY ASSURANCE AND INSPECTION	27
4.1	QUALITY ASSURANCE	27
4.2	INSPECTION AND TESTING	27
5.	ERECTION, CLEANING, START-UP AND PERFORMANCE TESTING	29
5.1	MECHANICAL ERECTION/ <i>CLEANING</i>	29
5.2	START-UP	29
5.3	PERFORMANCE/ACCEPTANCE TESTS	29
6.	DOCUMENTATION	31
6.1	GENERAL	31
6.2	DATA/REQUISITION SHEETS AND DOCUMENTATION REQUIRED AT THE TENDERING STAGE.	31
6.3	DOCUMENTATION AND INFORMATION REQUIRED AFTER CONTRACT AWARD	34
7.	REFERENCES	36

APPENDICES

APPENDIX 1	SCOPE OF SUPPLY AND TERMINAL POINTS	40
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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design, engineering, *material supply* inspection, site erection, start-up and performance testing of fired industrial type water-tube boiler installations.

CO boilers (in which the remaining carbon monoxide in the regenerator flue gas of a catalytic cracking unit is incinerated) may be an adaptation of a standard industrial type of boiler design. In this case, this PTS may be applied with few amendments. However, not all CO boiler designs will be covered by this PTS.

Excluded from the scope of this PTS are *Heat Recovery Steam Generators (HRSGs)* downstream of gas turbines (to which PTS 30.75.10.31 shall apply).

This PTS is not intended for once-through steam generators that are typically used for steam soaking and steam flooding in EP operations. Such steam generators are technically water-tube boilers but they do not have steam/mud drums or superheaters. They produce a low quality steam for direct injection into wells. Parts of this PTS, however, may be applied to the design of these steam generators.

This PTS is a revision of the PTS of the same number dated *July 1999*. This revision has not been extensive and a summary of the main changes is given in (1.5).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

When PTSs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

data/requisition sheets	PTS 30.75.10.93 (6 sheets), which shall be used by the Principal and the Manufacturer to specify the detailed requirements and proposals for a particular installation.
DCS	<i>Distributed Control System</i>
fuel	all fuels and combinations of fuels specified by the Principal for firing in the boiler.
HHWL	<i>High High Water Level (trip)</i>
HRSG	<i>Heat Recovery Steam Generator</i>
HWL	<i>High Water Level (alarm)</i>
IPF	<i>Instrumented Protective Function (safeguarding by instrumentation)</i>
LLWL	<i>Low Low Water Level (trip)</i>
LWL	<i>Low Water Level (alarm)</i>
maximum continuous rating (MCR)	the steam production under design conditions, measured downstream of the steam main stop/check valve and any de-superheater. It shall be measured upstream of any take-off of auxiliary steam.
NWL	<i>Normal Water Level</i>
peak load	110 % of MCR unless otherwise specified on the data/requisition sheets.
PEFS	<i>Process Engineering Flow Schemes (also known as Process and Instrumentation Diagrams, P&IDs)</i>
RMS	<i>Root Mean Square</i>

1.4 CROSS-REFERENCES

Where cross references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced in this PTS are listed in (7).

1.5 CHANGES SINCE PREVIOUS EDITION

This PTS is a revision of the PTS of the same number dated July 1999; the changes have been too extensive to be summarized here.

2. DESIGN AND ENGINEERING

2.1 GENERAL

This PTS specifies requirements for continuously operated base load boilers with low numbers of cold and hot start-ups (less than 100 and 200 respectively in a 25-year lifespan), and non cyclic operation, as typically encountered in oil refineries, chemical plants and gas plants.

It specifies requirements for both heavy duty dual fuel, heavy oil fired units, and light duty gas fired units (possibly with diesel-type fuel back-up facilities). Where requirements differentiate, reference is made to additional requirements for 'heavy duty' applications.

Heavy duty applications are residual fuel type fired units or units fired with waste (or other) gas streams of a fouling nature. The Principal will indicate in the requisition whether the boiler shall be considered heavy duty or not.

Design, fabrication, inspection, stamping, testing and erection shall be in accordance with ASME I and this PTS. Codes other than ASME I may be used if permitted or required by regulations and if approved by the Principal.

The Manufacturer/Supplier shall obtain all local code stamps and certificates needed.

The boiler shall be of the water-tube type, for liquid and/or gaseous fuels as specified, with forced-draught burner(s) and natural water circulation.

The boiler shall be suitable for outdoor operation.

The design shall be proven in practice, robust and capable of 3 years' continuous operation, and with not less than 6 years between major overhauls.

Safety, ease of operation, inspection, maintenance, repair and cleaning are of major importance.

The Manufacturer shall give full details of the chemical and physical properties of the construction materials.

There shall be sufficient space and access for inspection, cleaning, removal and maintenance of such parts as *drums*, tube bundles, headers, retractable burner parts, fixed and retractable sootblowers, valves, pumps, fans, turbines and electric motors. *Specific requirements apply to the accessibility of the flue gas path, superheaters and convective sections of heavy duty boilers.*

If there is danger of freezing during operation to equipment, parts, piping or drainage systems, protection against such freezing shall be provided.

The Principal shall specify the required efficiency, which will set design targets for the required fluegas exit (stack) temperatures.

Proven technology shall be applied to comply with the requirements for the emission of pollutants to the environment and optimize energy efficiency. *Emissions during normal operation, startup, shutdown, peak load, minimum load, and soot blowing shall comply with the local/state rules/ regulations and project specifications.*

2.2 PRESSURE PARTS

2.2.1 **Heating surfaces general**

2.2.1.1 General

All metal surfaces in contact with flue gas shall be at a temperature at least 15 °C (27 °F) above the highest dew point (acid or water as the case may be) which may occur during any of the operating conditions (excluding start-up) in combination with any of the fuels specified on the data/requisition sheets. The dew point calculation method shall be in accordance with API 560.

For heavy duty applications, convective heat transfer equipment shall have a square or rectangular pitch and sootblowers shall be installed. Otherwise, triangular pitch may be used.

Restriction orifices or reduced header bore for equalising flow distribution across parallel tubes shall not be used in any part unless approved by the Principal.

Individual tubes shall be supported and guided in order to prevent distortion (lateral movement > 1.5 tube diameter) and vibration of the tubes. For pendant type superheaters this requirement may be relaxed to 100 mm lateral movement.

For determination of the design temperatures an allowance for internal tube fouling shall be included. The following minimum inside fouling factors shall be applied to determine tube metal temperatures:

Economiser 4000 W/m² K (705 Btu/h·ft²·°F)

Evaporator 5880 W/m² K (1040 Btu/h·ft²·°F)

Superheater 11760 W/m² K (2075 Btu/h·ft²·°F)

These fouling factors do not need to be included in the thermal rating for the boiler. The responsibility for including sufficient fouling factors to achieve the guaranteed performance shall rest with the Supplier. The Supplier shall define the actual fouling factors considered for the design.

A full calculation of the maximum tube temperatures shall be provided to the Principal. These calculations shall be based on the peak heat flux derived from the circumferential heat flux distribution around individual tubes and the non uniformity within tube banks, and shall assume a flue gas mass flow and temperature unbalance of +12.5 % and 56 °C (100 °F) respectively.

2.2.1.2 Fin density and height

Extended surface tubing may be applied to fully convective heat transfer surfaces. Where finned tubes are applied, the fins shall be fully welded to the tube and be sufficiently rigid to withstand mechanical cleaning.

The maximum fin density, fin type and tube alignment depend on the type of fuel to be fired:

Minimum fin thicknesses of 1.3 mm (0.05 in) shall be applied for light duty gas firing and 2.5 mm (0.10 in) for heavy duty fuel oil/dual fuel firing respectively. The minimum fin pitch shall be 5.0 mm (0.2 in) for light duty gas firing and 12.5 mm (0.5 in) for fuel oil firing. For dual-fuel fired installations the limitations for fuel oil firing shall govern.

Maximum fin height for light duty gas firing is 19 mm (3/4 in) and 12 mm (1/2 in) for heavy-duty applications.

The fin type can be solid or serrated for light duty gas firing. For heavy duty fuel oil firing the fin type shall be solid or square/rectangular.

2.2.2 Boiler/combustion chamber

The firebox shall be entirely water-cooled. Furnace walls shall be of gas tight membrane or welded wall construction. The application of refractory shall be limited to burner throats, the top and bottom header of the circulation system and the sealing of (superheater) tube protrusions.

To minimise NO_x emissions and the risk of corrosion under insulation during shut downs, specifically in heavy duty boilers, the Manufacturer/Supplier shall apply sloping firebox bottoms so that floor tubes do not need to be covered with floor tiles, wherever possible. The furnace floor shall be partially or completely covered with refractory or bricks to avoid excessive vaporization if the tubes are within 15° of horizontal.

In heavy duty boilers, provision shall be made for draining the combustion chamber of the "wash-down" water that will be used at shutdowns. For cleaning of boilers, reference is made to PTS 70.10.80.11.

Membrane-type walls constructed from tubes and strips shall be used, and shall be welded over the whole length. Attachments to membrane walls shall be made to the strips/fins between tubes and not to the tubes themselves.

This PTS imposes no fixed limiting values on volumetric or superficial heat release rates in the furnace as these vary significantly with size and type of equipment. However, in sizing the firebox, the Manufacturer/Supplier shall take into account the following:

- The maximum local (peak) heat flux based on the projected tube surface exposed to the fireside shall be limited to 250 kW/m^2 ($79,250 \text{ Btu/h-ft}^2$) if the boiler feed water quality does not meet the specification in EN 12952-12:2003, Table 5.1 for demineralised feedwater for each individual component. Otherwise a peak heat flux up to a maximum of 400 kW/m^2 ($126,800 \text{ Btu/h-ft}^2$) is allowed as long as the peak heat flux does not exceed the Manufacturer's own standards.
- The need to limit the furnace exit gas temperature to avoid high temperature corrosion/overheating of the superheater tubes or other components. *This temperature limitation shall depend on the type of fuel fired and shall not exceed 1350°C (2462°F) for light duty gas firing or 1200°C (2192°F) for heavy duty applications.*
- The requirement to ensure completion of fuel burn-out in the combustion chamber *and to comply with the emission of unburned hydrocarbons/particulates.*
- *Burner Vendor's minimum requirements for distance between burners and for burner to side/rear wall distances. An additional wall clearance of at least 20 % shall be applied relative to the flame dimensions indicated by the burner Vendor.*
- *The fire box dimensions and design shall be such that complete combustion occurs within the furnace volume without flame impingement on side walls, roof or target walls during any operating condition. Impingement is defined as contact of the flame contour with any of the tubes. Flame contour can also be based on a predefined concentration profile of CO.*
- The requirement to comply with the defined emission limits of nitrogen oxides in the flue gases.
- *Circulation requirements as stated in section (2.2.5) shall be complied with.*

The Manufacturer/Supplier shall optimise the furnace design taking account of the above factors and provide the total heat release rate based on furnace volume [kW/m^3 (Btu/h-ft^3)] and the heat absorption rate [kW/m^2 (Btu/h-ft^2)] based on the projected furnace heat transfer surface. This information shall be based on the lower heating value of the fuel and MCR operating conditions and be provided on the data/requisition sheets. For the calculation of the above quantities the following definitions shall be used:

- *The furnace heat transfer surface is the projected surface of tube fraction and fins exposed to radiation of the planes which pass through the centres of all furnace tubes plus 10 % of the surfaces which are covered by refractory or floor tiles and including the front half of the tubes perpendicular to the flue gas flow where the flue gases reach the first convective heat transfer surface. The full circumferential surface of free hanging superheating panels in the firebox (e.g. platen superheaters) with a spacing between the panels of 300 mm or more can be added to the furnace heat transfer surface. If spacing is less, these superheater panels are considered the first convective heat transfer surface.¹*
- The planes as described above enclose the furnace volume.

Furnace tubes shall be bent around observation ports, access doors, sootblowers, burner ports etc., in order to make room for them. *No (intermediate) distribution headers or bifurcated tubes shall be applied in the 2 phase flow regime. For heavy duty boilers, the burner lay-out and the path of the flue gas through the boiler shall ensure symmetrical heat flux loading of the furnace walls and all convection coils. To achieve this, front wall (or tangentially fired) boilers with vertical gas flow furnaces and convection passes are specified.*

¹ Note: This definition slightly differs from the definition of EPRS (Effective Projected Radiant Surface)

Other boilers may have horizontal furnaces with flue gas flow diversion in the horizontal plane (e.g. D-type and bi-drum boilers).

2.2.3 Superheater

The superheater shall have a substantially flat temperature-load characteristic, so that excessive desuperheating ($>10\%$ of steam to grid) will not be necessary.

The steam flow shall be evenly distributed over parallel coils of the superheater(s) at MCR. The unbalance shall be maximum 3 % for the secondary and final stage superheater and maximum 8 % for the primary superheater. Headers with a length more than 2.7 m shall be equipped with multiple inlet nozzles with a maximum spacing of 2.7 m.

Also, care shall be taken in the design that the flue gas is uniformly distributed over the superheater coils, paying particular attention to the avoidance of flue gas bypassing.

All headers shall be outside the flue gas passage.

Superheaters with horizontal tube orientation shall be drainable. However, boiler designs including pendant superheaters with non-drainable loops are acceptable.

Arrangements shall be made and instructions shall be given, as necessary, to ensure adequate cooling of the superheater during start-up.

2.2.4 Steam temperature control

If the temperature variations of the superheated steam exceed the limits indicated by the Principal on the requisition, steam temperature control shall be accomplished by desuperheating, using spray water injection. If the boiler feedwater quality is not fully demineralised (refer to EN 12952-12:2003 Table 5.1) or contains non evaporative water treatment components, the Principal shall provide injection water from a separate uncontaminated source or, if no such water source is specified, an internal source shall be applied.

De-superheating via a heat exchanger submerged in the boiler's lower drum (in a bi-drum arrangement) is not accepted, as steam formation in this drum readily disturbs circulation.

De-superheating in the steam drum can be allowed if the Manufacturer/Supplier can prove that sufficient measures are taken to avoid effects on drum level (measurements) and steam quality. The maximum steaming rate in the steam drum due to embedded de-superheaters shall not exceed 5 % of MCR steaming production.

In order to ensure complete evaporation of the spray water, the steam temperature after desuperheating shall be maintained at a minimum of 25 °C above the steam saturation temperature in any design case.

The steam temperature downstream of the de-superheater station shall be confirmed to be dry and superheated by a temperature indicator reading above saturation temperature before entering a next superheater section (see Standard Drawing S 75.004). It is the Manufacturer/Supplier's responsibility to strictly adhere to the instructions of the de-superheater Supplier with respect to minimum upstream and downstream (straight) distance.

For thermowells in steam lines, the immersion length shall be based on steam velocity and temperature. The preferred immersion length is 75 mm (3 in) from the inside pipe diameter. The Supplier shall provide a thermowell vibration analysis (see also PTS 32.31.00.32).

2.2.5 Evaporators

All evaporators shall be of the natural circulation type.

The circulation ratio (ratio of total circulating mass / steam production) and the applied velocities in both convective evaporators and firebox shall:

- *As a minimum comply with Figure 1 for each circulation circuit/tube:*

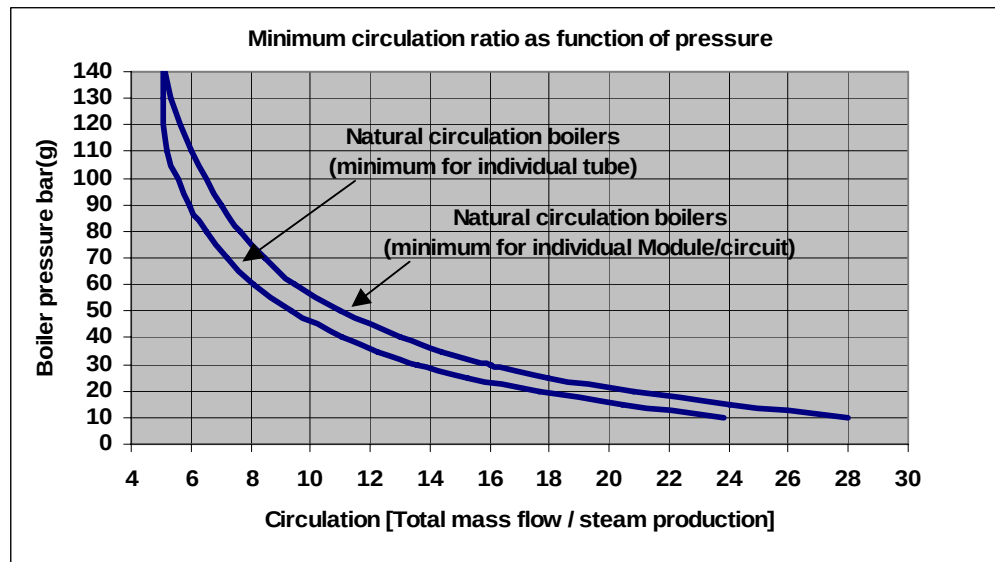


Figure 1: Minimum circulation ratio as function of drum operating pressure

Depending on the level detail of the Manufacturer/Supplier's circulation study, a minimum circulation ratio for tube modules shall be adhered to or a minimum circulation ratio in individual tubes.

- For horizontal tubes (inclination less than 20°), the superficial water velocity at any location shall be at least 1.0 m/s.
- To ensure equal distribution over all tubes, the design shall be such that a minimum of 75 % of the total pressure drop from drum outlet (inlet downcomer) to drum inlet (riser outlet) is created by the individual heat-exposed tubes. The riser, downcomer, inlet and outlet manifold design shall ensure maldistribution is maximum 5 % RMS at all operating conditions. The Supplier shall provide maldistribution calculations for approval to the Principal.

The velocities of water and steam at the inlet and outlet of the various sections of the evaporator system shall be recorded on the data/requisition sheets.

2.2.6 Economiser

Economisers should not generate steam under any condition unless special precautions are taken, since two-phase flow may lead to a maldistribution of flow or flow/pressure instability in the economiser coils. However, in heavy duty boilers with a vertical gas path, steaming may be accepted if:

- The superficial water velocity is above 1.5 m/s at MCR at any location. Other velocity criteria may be used, but are subject to approval by the Principal.
- The flow shall be entirely upwards without any low or high points.
- No intermediate headers are applied in the sections where the approach temperature is predicted to be less than 10 °C.
- The Supplier shall prove to the Principal that a non-steaming economiser is not reasonably possible within the thermal design of the boiler.
- The steam drum connection for a steaming economiser shall be located below the centre line of the drum and upstream of the primary stage steam/water separators.

A non-steaming economiser outlet line shall be connected below the minimum water level of the drum.

2.2.7 Drums

The drum design and arrangement shall ensure the required steam and water separation, distribution and circulation in conjunction with the rest of the boiler.

The water level in the steam drum is controlled within a narrow band so as to ensure:

- a constant supply of boiler water for cooling the radiant and convection sections;
- no water carry-over into the superheater.

Heavy duty boilers shall be single drum type. Otherwise a bi-drum arrangement can be applied.

In a single-drum boiler the drum shall be outside the flue gas passage.

Drum internals shall be accessible and cleanable with bolted construction and they shall be removable through manholes without modifying internals or the drum. *Manholes shall not be smaller than 450 mm x 400 mm (18 in x 16 in) elliptical. Manhole covers shall open inwards.*

Tube stubs, suitably prepared for welding, shall be provided at the drums if tubes are to be welded. Nozzles, stub ends for valves, fittings, mountings, tubes and anything to which drum internals etc. are to be secured shall be shop-welded into place. The length of the stubs shall be such that welding the tubes to the stubs will have no adverse effects on the drum or stub-to-drum connections.

Nozzles on drums/vessels shall not be smaller than DN 40 (NPS 1-1/2), for strength reasons.

The steam drum volume shall be adequate to accommodate a 25 % increase in steam generation, relative to the rated load, without drum water carryover. Drum water volume below the normal liquid level shall accommodate water shrinkage resulting from a 25 % decrease in steam generation, relative to the rated load, without actuating the low water alarm.

The size of the drum is also determined by the following requirements:

- A level difference of at least 150 mm (6 in) between normal level (NWL) and Low Level Alarm (LWL) and 150 mm (6 in) between normal level (NWL) and High Level Alarm (HWL).
- At MCR capacity, with continuous blow down at its normal value, and no feed water intake, a hold-up time of at least 60 s between low level alarm (LWL) and low-low level trip (LLWL).
- At no steam flow, with feedwater intake at MCR capacity, a response time of at least 30 s between high level alarm (HWL) and high-high level trip (HHWL).
- *The high-high level trip (HHWL) is at least 75 mm above high level alarm (HWL) and at least 150 mm below the secondary separators to ensure a good flow distribution to the separators.*

High-high level trip and low-low level trip shall only be installed if required by the Principal. The high-high level trip is intended to prevent carry-over for the protection of downstream equipment. It initiates a trip of the boiler feed water supply and the burner firing; these being activated after a 60 s time delay. The low-low level trip stops the burner firing so as to protect tubes from inadequate cooling.

The normal water level, the low-low trip level and the maximum trip level shall be indicated by engraved marks both on the drum(s) and on the level gauges. *Engravings shall protrude outside the insulation.*

The feed water distribution manifold shall be provided to distribute water equally along the length of the drum. Steam and water shall be separated evenly over the length of the drum.

The feedwater inlet connection(s) on the steam drum shall be designed with a thermal sleeve when the approach temperature is greater than 55 °C (100 °F) for any operating condition, or when required by the design code.

The steam drum internals shall be designed for a water carry over of less than 0.05 % by weight in steam for all operating conditions.

The steam drum shall have factory installed steam separators of sufficient capacity to reduce liquid carry over to the superheater in all operating conditions to 0.05 % mass. The Principal shall specify an alternative limit if required to fulfill the steam quality targets.

2.2.8 Downcomers

Downcomers shall be as near to the bottom of the drum as practicable to permit maximum use of drum water content. Downcomers shall be equipped with covers and/or vortex breakers to avoid vortexes in drum level surface and vapour entrainment in the downcomer, and to protect them from alien materials during drum inspection/maintenance.

In non heavy duty type boilers, downcomers may be (partially) heated provided that the following conditions are fulfilled:

- Downcomers and riser shall be separated by drum internals so that only dedicated risers and downcomers does are present.*
- For all tubes assigned as downcomers, the heat flux shall be so low that even if 3 times the expected heat flux is applied at the expected circulating mass flow, the water remains in single phase water flow.*
- The application of heated downcomers is restricted to the low temperature zones of the boiler where the flue gas temperature is below 600 °C (1100 °F) in any design case.*

Water velocity in unheated downcomers shall be limited to 4.5 m/s (15 ft/s) maximum. In heated downcomers the velocity is limited to 1.5 m/s (5 ft/s).

Bottom distribution headers shall be equipped with nozzles/flanged ends to allow inspection of these headers and the water distribution piping to individual tube headers.

2.2.9 Air preheater

Air preheaters shall not be applied if the temperature of the feedwater entering the boiler is 20 °C or more below the flue gas stack temperature required to achieve the specified efficiency.

An air preheater is normally not applied for heavy duty boilers.

If an air preheater is required, the size of the economiser shall be designed with an approach temperature between 10 °C (20 °F) and 30 °C (50 °F) at MCR.

The design of the air preheater shall take into account the minimum allowable metal temperature defined in (2.2.1) for minimum ambient temperature design.

Flue gas acid dew point shall be calculated and stated by the Vendor, and any features for minimizing external coil corrosion shall be identified. A steam preheater can be installed in the airflow upstream of the air preheater to protect the air preheater from dew point corrosion. To avoid rapid fouling and ensure sufficient mechanical robustness, this steam preheater shall have not more than 236 fins/m (6 fins/in), the fins shall be not higher than 19 mm (¾ in), and the tube diameter shall be not less than 19 mm (¾ in).

The air preheater shall be provided with an air by-pass system to control the its flue gas exit temperature. Such a system shall have mechanically interlocked isolating dampers, to direct air to the air preheater or air by-pass, as required.

Recuperative air preheater designs with cast iron tubes or open channels are acceptable. Regenerative type air preheater designs (e.g. rotary type air preheater) shall not be considered.

The flue gas side of recuperative air preheaters shall be equipped with automatically operated rake type sootblowers and water wash system.