

PETRONAS TECHNICAL STANDARDS

MANUAL

GAS TURBINE HEAT RECOVERY

STEAM GENERATORS

PTS 30.75.10.31

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This revision of **PTS 30.75.10.31 – Gas Turbine Heat Recovery Steam Generators** 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 30.75.10.31 (December 1999)** will be removed from PTS binder/ e-repository from herein onwards.

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PREFACE

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TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS AND ABBREVIATIONS	5
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES SINCE PREVIOUS EDITION	7
2.	DESIGN AND ENGINEERING	8
2.1	GENERAL	8
2.2	MAJOR PRESSURE PARTS.....	8
2.3	ROTATING EQUIPMENT	14
2.4	TURBINE EXHAUST GAS AND FLUE GAS SYSTEM	14
2.5	AUXILIARY FIRING SYSTEM	22
2.6	BOILER MOUNTINGS.....	23
2.7	MATERIALS, FABRICATION AND STRUCTURES.....	25
2.8	PRESERVATION AND INITIAL PREPARATION.....	32
2.9	NOISE LIMITATIONS	32
3.	INSTRUMENTATION AND CONTROL	34
3.1	GENERAL	34
3.2	FUNCTIONAL DEFINITION OF INSTRUMENTATION AND CONTROLS	34
4	INSPECTION AND TESTING	35
4.1	GENERAL	35
4.2	SPECIFIC	35
5.	DOCUMENTATION	36
5.1	GENERAL	36
5.2	DATA/REQUISITION SHEETS.....	36
6.	REFERENCES	37

APPENDICES

APPENDIX 1	SCOPE OF SERVICES AND SUPPLY AND TERMINAL POINTS.....	41
APPENDIX 2	NON-HRSG SPECIFIC DESIGN AND SCOPE ITEMS POSSIBLY INCLUDED IN SUPPLIER'S SCOPE.....	44
APPENDIX 3	TYPICAL OVERVIEW OF DOCUMENTATION AND INFORMATION EXCHANGE FOR HRSG PROJECTS.....	47

1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design of Heat Recovery Steam Generators (HRSGs) suitable for continuous operation in conjunction with a single gas turbine.

Appendix 1 gives a typical 'Scope of supply' and 'Terminal points' to assist the Principal in specifying an HRSG. Appendix 2 specifies requirements for non-HRSG equipment and becomes applicable if the Principal so specifies.

This PTS covers both unfired and fuel gas auxiliary fired HRSGs of both the forced and natural circulation types. It can be applied to both single-pressure and multiple-pressure HRSGs, but special arrangements like integrated deaerators or low temperature condensate preheaters are not covered.

Although this PTS specifically describes HRSG for gas turbine applications, it can also be applicable to heat recovery units recovering heat from other (clean) processes. When this PTS is used for non gas turbine applications, the user shall scrutinise and amend this PTS where required.

This PTS is more limited in application (HRSGs downstream of gas turbines only) and type (water tube HRSGs only) than API RP 534. However, this PTS is far more specific and detailed for this particular HRSG application. Therefore this PTS is maintained as a standalone document instead of being turned into "amendments to API RP 534".

This PTS is a revision of the PTS of the same number dated December 1999. This revision has been extensive. 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 PETRONAS companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in exploration and production facilities but, where required, it may also be used in oil refineries, chemical plants, gas plants, and supply/distribution 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 the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS AND ABBREVIATIONS

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** indicate a requirement.

The word **should** indicate a recommendation.

1.3.2 Specific abbreviations and definitions

auxiliary firing	firing of fuel in the TEG to supplement the heat input to the boiler (synonymous with co-firing)
boiler	synonymous with steam generator
boiler code	design code of the boiler, specified by the Principal (e.g. ASME I or EN 12952)
CFD	Computational Fluid Dynamics
co-firing	firing of fuel in the TEG to supplement the heat input to the boiler (synonymous with auxiliary firing)
fresh air operation	An auxiliary firing system which allows continued HRSG operation when the gas turbine is not in use. The air is provided by means of fan(s).
fuel	all fuel gases specified by the Principal for firing in the boiler
HRSG	Heat Recovery Steam Generator
HHWL	High High Water Level (alarm before trip)
HWL	High Water Level (alarm)
IPF	Instrumented Protective Function (safeguarding by instrumentation)
LLWL	Low Low Water Level (alarm before trip)
LWL	Low Water Level (alarm)
maximum continuous rating (MCR)	Maximum output (steam production) the boiler is capable of producing continuously under design conditions and normal conditions, measured upstream of any take-off of auxiliary steam and vent valve but downstream of any desuperheater
NWL	Normal Water Level
peak load	110 % of MCR, unless otherwise specified on the requisition
PEFS	Process Engineering Flow Schemes (also known as Process and Instrumentation Diagrams, P&IDs)
requisition	data/requisition sheets PTS 30.75.10.94 (9 sheets), which shall be used by the Principal and the Manufacturer/Supplier to specify the detailed requirements and proposals for a particular installation
TEG	Turbine Exhaust Gas

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 (6).

1.5 SUMMARY OF MAIN CHANGES SINCE PREVIOUS EDITION

The previous edition of this PTS was dated December 1999. Compared to the previous edition this document has been extensively revised and it is impractical to list all the changes here. The most significant changes are:

- *Specifications for superheater, evaporator, economiser and downcomer design*
- *Selection of fire box types, determination of hot face design temperatures and requirements for lining design.*
- *Requirements for relief valve sizing are clarified.*
- *Tube fins. Allowable numbers per metre and fin height, and quality requirements have been amended.*
- *Many sections not specific to HRSG design have been moved to an Appendix for consideration only. Scope, services by Supplier, electrical and instrumentation design requirements, and noise and quality assurance requirements shall be specified by the Principal.*

2. DESIGN AND ENGINEERING

2.1 GENERAL

The boiler shall be of the water-tube type and be suitable for continuous operation in conjunction with a single gas turbine. The boiler shall be suitable for outdoor operation.

The design shall be proven in practice, robust, reliable, safe and easy to operate.

The design shall be based upon largest possible factory built modules with as much equipment as practicable factory assembled.

In an auxiliary fired boiler, the MCR and peak load of the boiler shall be achieved over the turbine load range specified by the Principal on the requisition.

In a boiler which is not equipped with auxiliary firing, the MCR shall be specified at the maximum continuous site load of the turbine. In such a case, the peak, base and minimum loads of the turbine shall also be specified on the requisition.

The HRSG shall be capable of reaching the final steam temperature over the load range (of gas turbine and HRSG) as specified by the Principal.

All deviations of the Manufacturer/Supplier equipment from this PTS shall be listed by the Manufacturer/Supplier, and this list shall be forwarded with the completed requisition.

The applicable local regulations shall be stated by the Manufacturer/Supplier on the requisition.

The Manufacturer/Supplier shall only utilise standard materials according to internationally recognised material codes for the construction materials and shall clearly indicate which materials are utilised in which boiler section.

If there is danger of freezing during the operation or drainage of any part, protection against such freezing shall be provided.

Energy conservation shall be optimised and the emission of pollutants to the environment shall be minimised.

Design, selection of equipment and materials and corrosion protection shall be based on a design lifetime of 25 years.

2.2 MAJOR PRESSURE PARTS

2.2.1 General

The Principal shall specify the boiler code to be applied to the main equipment.

External power piping shall be in accordance with the standards specified by the boiler code.

The Manufacturer shall obtain all code stamps and certificates required by local regulations. Stamping in accordance with e.g. ASME 1 PG 105 is not required unless specified in the applicable regulations. However the design, construction, inspection, etc. shall be in compliance with the specified boiler code. The Manufacturer's own stamping of boiler in accordance with e.g. ASME 1 PG-106 shall be deemed adequate.

The HRSG shall be designed to be operated at the maximum recommended concentration of dissolved solids, ion concentrations and conductivity in accordance with EN 12952-12 (i.e. operate continuously with the poorest allowable water quality).

2.2.2 Drums

The steam drum shall be entirely outside the flue gas passage.

Drum internals shall be accessible and cleanable, and they shall be fully bolted and removable without damaging the drum. Tube stubs, suitably prepared for welding, shall be provided at the drums if tubes are to be welded at site.

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.

The size of the drum is to be determined by the following requirements:

- a level difference of at least 150 mm between NWL and LWL and 150 mm between NWL and HWL.
- At MCR capacity, with continuous blow down at its normal value, and no feedwater intake, a hold-up time of at least 60 s between LWL and LLWL.
- At no steam flow, with feedwater intake at MCR capacity, a response time of at least 30 s between HWL and flooded drum internals (HHWL if installed).

The NWL, LLWL and HHWL shall be indicated by engraved marks both on the drum(s) and on the level gauges.

The supply of feedwater to the drum and the separation of steam and water shall be affected evenly over the length of the drum.

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

The drum(s) shall be accessible from both sides via manholes (minimum size 450 mm × 400 mm). The manhole covers shall be supported by hitches/davits.

2.2.3 Downcomers

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.

Heated downcomers can only be acceptable if they are placed in low heat flux zones and circulation is sufficient to avoid steaming in the downcomer under all conditions including rapid pressure changes in the evaporator. To ensure this, the downcomer shall remain free of vapour in steady state conditions at 3 times the calculated maximum heat flux.

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

The top distribution headers shall be equipped with handholes to allow inspection of these headers and tubes.

2.2.4 De-superheater

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 of insufficient purity or contains non evaporative components, the Principal shall provide injection water from a separate uncontaminated source.

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 for any design case.

The steam temperature downstream of the desuperheater 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 Drawings S 24.010 and S 75.004). The Supplier shall comply with the instructions of the desuperheater Supplier with respect to the minimum straight distance upstream and downstream of the desuperheater.

The thermal design of the boiler shall be balanced so that the total injection water flow shall not exceed 10 % of superheater steam supply to the steam header.

For water injection valve the suppliers shall supply a design that is proven in practice, robust, reliable, safe and easy to operate.(Plug type valve)

2.2.5 Heating Surfaces

2.2.5.1 General

In properly designed HRSGs tube failures are a rare occurrence. Nevertheless, tube repair or plugging shall be addressed in the design. To facilitate the repair and identification of failed tubes, tube banks shall not consist of more than 10 tube rows if there is a screen evaporator, superheater or economiser. For evaporators not directly exposed to the maximum flue gas temperature, this may be increased to 14 tube rows.

NOTE: If the design allows for a different repair method than having to cut healthy tubes to reach a failed tube, then the above requirements may be ignored if the Principal agrees.

The design of the tube banks and casing shall be such that the possibility of flue gas bypassing the coils is minimised. Therefore the free space between the casing wall and the nearest tube/fin tip in hot position shall not be larger than half the free space between adjacent tubes/fin tips in the rest of the tube bank. If necessary, e.g. if a triangular tube pitch is used, strips or corbels shall be applied to reduce the flow gap.

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

Individual tubes shall be supported and guided in a satisfactory manner so as to prevent distortion (lateral movement of more than $1.5 \times$ tube diameter) and damage due to vibration of the tubes.

Tube bank coils shall be supported by a steel structure and shall not rest on internal insulation or cladding. Unless otherwise accepted by the Principal, coil banks shall be top supported and downward expanding.

The coils shall be designed so that no significant mechanical forces due to thermal expansion of the tubes or their supports will occur. No coil constructions subject to stresses due to differences in thermal expansions (like multiple superheater tube rows exposed to different heat fluxes fixed between the same top and bottom header), or meandering flow patterns (downward and upward flow between the same top and bottom header with baffles in headers) are allowed unless neither the difference between process inlet and outlet temperatures nor the maximum metal temperature difference in the module exceeds 25 °C.

Cross-over piping shall be inside the boiler casing and shall be of the same material and design temperature/pressure as the next header (in the steam/water flow direction). The number of casing protrusions shall be minimised.

Tube-to-header welds, butt-welded tubes or pipes, and crossovers shall not be exposed to high heat flux. If such connections are applied within the boiler casing they shall be located outside the main flue gas flow and shielded by a reasonable gas-tight construction of baffle plates and tube sheets.

A straight tube or pipe in a tube bundle shall not be composed of two butt-welded parts, unless approved by the Principal.

An allowance for internal tube fouling shall be included in the design temperatures. The following fouling factors shall be applied to determine operating temperatures:

Economiser	4000 W/m ² .K
Evaporator	5880 W/m ² .K
Superheater	11760 W/m ² .K

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 is left to the Supplier.

2.2.5.2 Fin density and height

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

Clean gas:

If gas of sales quality as typically found in public natural gas grids or gases of equivalent quality, free of solids and with an atmospheric dew point of at least -20°C is fired, the following shall apply:

- The minimum acceptable fin thickness is 1.25 mm.
- The maximum fin density shall not exceed 197 fins per metre and the height shall be maximum 12.7 mm.
- A maximum fin density of 236 fins per metre and a maximum fin height of 19.1 mm may be applied in low heat flux/temperature zones where the flue gas temperature is below 500°C .
- Serrated (twisted) fins are acceptable.
- Staggered tube alignment is allowed.

Other gases and incidental light oil firing on the gas turbine (back up fuel only, < 2 % of operating time):

If the solids concentration (soot) in the flue gas is less than 0.2 mg/m^3 in dry flue gas corrected to 3 % oxygen, the following shall apply:

- The maximum fin density shall be 157 fins per metre; the minimum fin thickness shall be 1.5 mm and the maximum fin height shall be 12.7 mm.
- Fins shall be solid.
- Inline tube alignment is required.

All other applications:

The fin density and thickness, tube arrangement and the installation of cleaning facilities shall comply with the oil-fired requirements of PTS 31.24.00.30 or as otherwise specified by the Principal.

2.2.5.3 Superheater

The superheater shall have a substantially flat temperature-load characteristic, so that excessive desuperheating will not be necessary (see 2.2.4 for limits). If a membrane-type wall furnace is applied, superheater headers shall be outside the flue gas passage.

The steam flow shall be evenly distributed across parallel coils of the superheater(s) at all loads (i.e. no coil shall have a flow rate that is more than 5 % different from the average flow rate). The pressure drop over the parallel superheater passes, compared to dynamic flow effects in the headers, shall be such that flow maldistribution is minimised.

The steam velocities in the tubes shall be at least 20 m/s at MCR, and the number of tube rows (in the flue gas direction) between the same top and bottom header shall be not more than 2.

If the superheater is subject to radiation (every HRSG with a flue gas temperature entering the first tube row above 650°C) the superheater shall be typically shielded by 3 rows of screen evaporator tubes. If this is not possible for performance reasons (for instance the specified steam temperature cannot be obtained in an unfired HRSG) the first 3 rows in the superheater shall be bare and only contain 1 tube row between the same top and bottom header.

Superheaters shall be designed so that the mechanical stresses resulting from differences in tube wall temperature between tubes are minimised. If the proposed design may suffer mechanical stresses, the Supplier shall prove at the Principal's request that material stresses remain below the allowable stresses according to the relevant piping design code (i.e. ASME B31.1) when the full tube wall temperature differences due to radiation, flue gas maldistribution and flue gas temperature differences are taken into account. The Vendor shall prove that the thermo-mechanical stresses are low enough to permit a fatigue design life commensurate with the design life of 25 years. The number of cold start-ups shall be assumed to be at least 25 per year. Major operational stress cycles shall be identified by the Vendor/Principal and taken into account. Fatigue stresses shall be determined by an appropriate method such as a pipe stress analysis program corrected for the presence of weld profiles, or a detailed numerical stress analysis.

Drainable superheaters shall be selected. Only if there is a process or mechanical reason for a non-drainable superheater (e.g. a water cooled furnace, continued in the superheater section), can non-drainable superheaters be accepted provided that the envisaged sum of cold and warm starts and stops (including trips) of the HRSG is less than 10/year.

In that case the start-up procedure shall include provisions for gradual start-up, to allow for evaporation of accumulated water in the superheater tubes. The selection of a non-drainable superheater shall be subject to approval by the Principal.

Arrangements shall be made and instructions shall be given to ensure adequate cooling of the superheater during start-up and safety relief (refer to 2.6.1).

2.2.5.4 Evaporator

The maximum local peak heat flux, under any operating condition, shall nowhere exceed 250 kW/m².

Natural circulation vertical tube evaporators are preferred to forced circulation (horizontal) tubes. Other arrangements such as inclined tubes, horizontal tubes or combined vertical/horizontal tubes can be considered if the minimum circulation ratios and mixture velocities as specified below can be achieved with an elevated location of the steam drum. Such a system should only be allowed if clear evidence of the successful application of the proposed natural circulation principle in a similar installation (temperature, heat fluxes, flue gas direction and pressures) can be satisfactorily demonstrated by the Supplier.

The mixture velocity and circulation ratio shall be such that, at all boiler loads, the steam/water two phase mixture will not suffer phase separation (stratified or stratified-wavy flow), which causes local dry-out of the internal tube surface and subsequent salt deposition, caustic gouging and/or tube overheating.

The circulation ratio (ratio of total circulating mass to MCR steam production) and the applied velocities in the boiler shall as a minimum comply with the graph below for each circulation circuit/Module/tube row:

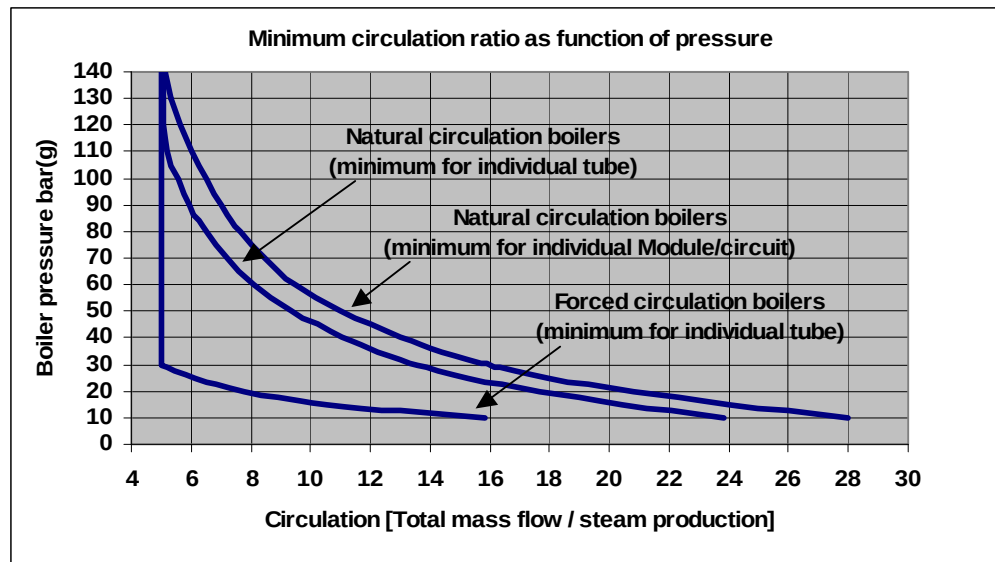


Figure 1 Minimum circulation ratio as function of drum operating pressure

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

- For forced circulation boilers: The water velocity at the inlet of each individual pass shall be minimum 1.75 m/s while the mixture outlet velocity shall not exceed 25 m/s (criteria based on no diameter changes in passes).
- For natural circulation horizontal tubes, the water velocity at the inlet of each individual pass shall be at least 1 m/s (criterion based on no diameter changes in passes).
- The circulation ratio should be at least equal to the minimum requirements set by the Supplier for the proposed design and water quality.

For forced circulation boilers the water circulation and content in the tubes shall remain sufficient to protect the coils:

- during the period between breakdown of one circulation pump and take-over by the spare pump;
- against the residual heat accumulated in the boiler during a complete power failure.

2.2.5.5 Economiser

Amended per
Circular 126/08

All metal surfaces in contact with flue gas shall be at a temperature at least 15 °C 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 in the requisition. The dewpoint calculation method shall be in accordance with ISO 13705.

The economiser shall not generate steam, as this may lead to stagnant conditions in downwards flowing tubes across the parallel coils (vapour locks). Taking into account flue gas and water maldistribution, the economiser is deemed to potentially generate steam during upsets and transitions if any of the design cases has a water temperature within 7 °C of the saturation point.

Neither steaming nor an approach point of less than 7 °C is permitted unless there is entirely upwards flow in the last economiser coil section. Another option is to apply 'anti-steaming' features like a feedwater control valve downstream of the economiser.

'Anti-steaming' measures are subject to the Principal's approval and shall be supported by evidence of successful comparable systems.

The acceptable level of steaming and the mixture flow velocities shall be in line with the requirements for evaporators.

In this case, the steaming economiser shall be connected to the drum as if it were an evaporator riser to avoid any interference with drum level measurement and steam purity.

2.3 ROTATING EQUIPMENT

2.3.1 Circulating pumps

Boilers with forced circulation shall have two 100 % duty circulating pumps, suitable for unrestricted parallel operation.

One pump shall satisfy all requirements. The second pump shall be used only upon failure of the first pump.

The margin between net pressure suction head available (NPSHA) and net pressure suction head required (NPSHR) shall take into account reduced NPSHA due to fouled strainers, or when drum operating pressure is dropping rapidly. A margin of at least 3 m shall be maintained.

Unless specified otherwise by the Principal, to cope with power failures the normally operating pump shall be steam turbine driven and the stand by pump shall be electric motor driven. Consequently, the steam turbine does not require auto cut in facilities.

2.3.2 Forced-draught fans

Standby forced draught fans, intended to supply combustion air following a gas turbine trip, shall not be supplied unless specified by the Principal. The Manufacturer/Supplier shall indicate any limitation on the steam output of the boiler during operation with a standby fan, if this is applied.

Auxiliary air fans, purge air fans, ignition burner air supply fans (2.5.3) and sealing air fans (2.4.2) shall be provided if required.

When purge air, ignition burner air and sealing air (or any combination of these) are required they shall be supplied by one common set of two 100 % duty fans.

2.4 TURBINE EXHAUST GAS AND FLUE GAS SYSTEM

2.4.1 Gas flow induced vibrations

The Manufacturer/Supplier shall include in the design all measures necessary to ensure that no part of the boiler installation and ducting shall be subject to vibrations that may reduce the lifetime of any part of the boiler and ducting, or create equipment noise exceeding the limitations described in (2.9).

Frequencies of gas vortex shedding from the tubes shall not excite or resonate with the natural frequencies of the tubes.

In addition, such vortex shedding frequencies shall not excite or resonate with the acoustic frequencies of the boiler casing or ducting.

The Manufacturer/Supplier shall provide a vibration analysis report showing Strouhal numbers, and the gas vortex shedding frequencies for each tube bank, as well as the lower natural frequencies of the tubes, and the acoustic frequencies of the boiler casing taking into account the presence of tubes. If, after initial start-up, it is found that corrective action to reduce vibration is necessary, it shall be the responsibility of the Manufacturer/Supplier to apply corrective measures prior to the hand-over of the boiler to the Principal. However, the corrective measures applied shall be subject to the approval of the Principal.

2.4.2 Firebox observation

Air-cooled observation windows and peepholes shall be provided on supplementary fired boilers and shall afford a view of burners, flames and surfaces liable to flame impingement. The observation windows/peepholes shall provide at least:

- a 50 % view of the total duct burner plane of a matrix duct burner, with at least 25 % of each individual burner;
- a 100 % view of all burner throats of register type burners;
- a view of all pilot flames;
- a cross-sectional view at the furnace outlet covering the area closest to the burners to verify flame lengths and absence of flame impingement;
- views parallel to all membrane walls at burner elevation to verify the absence of flame impingement on furnace walls.

The glasses shall be protected on the hot side by pivoting metal plates. The glasses, frames and view tubes shall be equipped with air supply for purging and cooling.

Air for any of the above purposes shall not be supplied by the instrument/plant air system but by two 100 % duty purge air fans combined with the ignition burner air supply and damper seal air supply (where applicable). Each purge air fan shall be capable of supplying at least 125 % of the nominal required air for all observation windows, ignitors and damper seals in order to reduce the risk of overheating.

Purge air capacity, supply lines and connections shall be designed to maintain at least 1 m/s velocity over the internal cross-section of the view tube (regardless of the view hole diameter), or to maintain a pressure in the observation window sleeve of 15 mbar higher than the highest TEG pressure.

2.4.3 Flue gas path access

There shall be an access door and access space upstream and downstream of each tube bank and ducting separation (burners, dampers or flow straightening devices). For access doors in water tube walls a minimum free opening of 400 mm diameter (circular) or 400 mm x 400 mm (rectangular) is allowed, whereas in other duct walls a rectangular opening of at least 600 mm x 600 mm is required. The minimum distance for access between convective tube banks shall be 700 mm.

2.4.4 Ducting general

The ducting includes all gas turbine exhaust ducts, the HRSG casing, the sections for the auxiliary firing burners, and the ducts, transition sections and expansion joints as far as the stack.

The HRSG casing walls shall be constructed of steel plate, 6 mm minimum thickness. The casing shall have a design pressure based on the most severe combination of the wind pressure/suction and 1.5 times the maximum operating pressure in the casing, but not less than 50 mbar. If a combined stack outside the Supplier's scope is used, the Principal shall specify the vacuum design pressure (maximum draught), and maximum back pressure.

Ducting shall be sufficiently rigid to prevent damage from vibration and avoid drumming when exposed to gas turbine exhaust flow over the complete flow range. Duct sections shall be suitably stiffened to minimize distortion and withstand seismic and wind loads. Effective vibration isolation from the gas turbine is particularly essential.

Duct plate shall be designed to limit the deflections to 1/100 of the span of plate between stiffeners, taking full advantage of multispan continuity where appropriate, under design conditions.

Duct stiffeners shall be designed to limit deflection to 1/240 of the stiffener or support span under design conditions.