



STANDARD TECHNICAL FEATURES OF BTG SYSTEM FOR SUPERCRITICAL 660/ 800 MW THERMAL UNITS



Government of India
Ministry of Power
Central Electricity Authority
New Delhi – 110066

JULY, 2013



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A. S. BAKSHI
Chairperson
Central Electricity Authority &
Ex-officio Secretary
Government of India

F O R E W O R D

Large capacity addition has been envisaged in the country for next two decades with a target of about 80,000 MW envisaged in 12th five year Plan. Most of the future capacity addition is envisaged to come from large size supercritical units as for their advantage of higher efficiency/ reduced heat rate and accordingly reduced environmental emissions.

With opening of electricity generation to the private sector, a large number of IPPs have come into being and are handsomely contributing to country's capacity addition targets. Further, a number of joint ventures have been set up in the country and some are in the process of being set up for manufacturing of power plant equipment with collaboration with international manufacturers, having varying design, manufacturing and operating practices. In this respect, a need was felt to have a document on standard technical features of supercritical units which could cover for varying practices of different suppliers and users and serve as a useful reference document. Accordingly, CEA had set up a Committee under Member (Thermal) in August 2009 with participation from major utilities, IPPs, manufacturers and engineering consultants for developing standard technical features of BTG system for 660/ 800 MW supercritical thermal units.

Based on inputs received from participant members on two draft versions over a period of time, CEA has finalized the standard technical features of BTG system for 660/ 800 MW supercritical thermal units. The document reflects the pooled experience and knowledge of participating engineers from CEA, utilities, IPPs, manufacturers and engineering consultants.

I hope this document shall find very useful application by all, particularly new utilities in selection of appropriate equipment for supercritical plants being set up by them.

I wish to express my appreciation and sincere thanks to all the members of the Committee who have shared their experience and made valuable contribution in bringing out this document.

(A. S. BAKSHI)

New Delhi
July, 2013



MANJIT SINGH
Member (Thermal) & Chairman of Committee
Central Electricity Authority &
Ex-officio Additional Secretary
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P R E F A C E

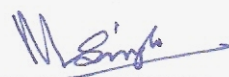
CEA had set up a Committee in August 2009 with participation from major utilities, IPPs, manufacturers and engineering consultants for preparation of standard technical features of BTG system for 660/ 800 MW supercritical thermal units. The Committee held meeting in CEA in October 2009. The first draft document was prepared by CEA in August 2010 and circulated to the committee members for their comments/ suggestions. The document broadly covers the design criteria, equipment features, layout aspects, performance guarantees etc. of major items of BTG system viz. boiler, turbine, generator, their auxiliary systems and key aspects of BTG C&I system.

Based on comments/ suggestions received and a comprehensive review of first draft carried out by CEA, second draft was prepared by CEA and circulated to committee members in July 2012. Keen interest has been taken by committee members on this document and detailed comments/ suggestions were received on it from them over a period of time. These have been reviewed by CEA considering normal practices being followed in the country and taking a balanced view on varied practices of different manufacturers/ utilities/ IPPs/ consultants. The document on standard technical features of BTG system for 660/ 800 MW supercritical thermal units has been now been finalized by CEA based on above review and same is considered to represent the best collective wisdom of participant engineers from CEA, utilities, IPPs, equipment manufacturers and consultants.

I am sure that utilities, IPPs, and equipment suppliers would benefit from this document and find it very useful for their future projects on supercritical power plants.

I wish to express my appreciation and sincere thanks to all the members of the Committee from CEA, NTPC, BHEL, APGENCO, MAHAGENCO, RRVUNL, Tata Power, Adani Power, Reliance Infra, L&T- MHI, Toshiba India, Alstom India, TEC and DCPL for sharing their rich experience and making valuable contribution towards finalisation of this document.

New Delhi
July, 2013


(MANJIT SINGH)



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SECTION -1

GENERAL



CHAPTER 1

INTRODUCTION

1.1 Supercritical Technology

The current thrust of thermal power development in the country is on supercritical units so as to improve the conversion efficiency and reduce carbon footprint. A number of power generation utilities are going for supercritical technology and a large number of supercritical units of 660/800 MW size are already under construction. Apart from BHEL and L&T, several other manufacturers are setting up facilities for manufacturing supercritical boilers and turbine generators in the country. Considering these developments, this document on “Standard technical features for BTG system of supercritical 660/800 MW thermal units” has been prepared with a view to evolve common understanding amongst utilities, manufacturers and consultants on design and sizing philosophy for supercritical units. The objective is to incorporate broad functional aspects deemed necessary for specifying major quality and performance parameters unambiguously; and at the same time provide flexibility to the manufacturers. Steam generator and auxiliaries, being the major focus area for supercritical units, have been dealt with in more detail. This document is not intended to be detailed specification for use as bid document.

The generation efficiency of coal fired stations depends on the steam parameters adopted - higher the steam parameters, higher is the efficiency. It is with this objective that the steam parameters have been constantly raised from 60 kg/cm² for 50 MW units to 170 kg/cm² for 500 MW units. Supercritical technology implies use of steam pressure beyond the critical point of water/steam which is about 225 kg/cm². Thus, supercritical units use higher steam parameters of over 240 kg/cm² with various combinations of temperature and pressure. This has been made possible largely through developments in materials technology to withstand the higher temperatures and pressures in the boiler.

World over the supercritical technology has been driven by the need to achieve higher efficiency in order to reduce specific fuel consumption and green house gas emissions. Supercritical technology is an established and proven technology with over 500 supercritical units operating worldwide and reliability and availability of supercritical units being at par with that of sub-critical units. Ultra supercritical parameters with pressure of 250-300 kg/cm² and main steam/ reheat steam temperatures of 600/610⁰C are also being adopted. Research is underway to further increase the steam temperatures to 700⁰C.

Whilst the earlier supercritical units installed in the country adopted steam parameters of 247 kg/cm², 535/565⁰C, higher steam parameters of 247 kg/cm², 565/593⁰C are being adopted for later units and have been adopted in this



document. The Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, stipulate the maximum turbine cycle heat rate for supercritical units as 1850 kcal/kWh with turbine driven BFP and 1810 kcal/kWh with motor driven BFP and this would require adoption of minimum steam parameters of 247 kg/cm², 565/ 593⁰C at turbine inlet. Efficiency improvement of about 2.38 % over the present 500 MW sub-critical units is expected with these minimum steam parameters. Parameters higher than above may also be adopted to achieve better heat rate/ efficiency as per standard practice of OEM.

Supercritical technology being a recent introduction in the country, a brief introduction of this technology along with implications on design/construction has also been covered hereunder.

1.2 Implications on Design/Construction

Adoption of supercritical technology involves several design/construction changes intrinsically associated with this technology. Some other issues also emanate due to larger unit size of supercritical units. These are discussed as under:

1.2.1 Evaporator design

Unlike at sub-critical pressures, there is no co-existence of the two phases, water and steam at supercritical pressures and there is no fixed transition point for phase change like the drum in sub-critical boiler acting as evaporation end point. Therefore the standard circulation system (natural/assisted), which relies on the density difference between steam and water and steam separation in drum is no longer suitable for supercritical units. Instead, supercritical units necessarily use a once-through type of boiler. These boilers also operate in subcritical recirculation mode, subcritical once-through mode and supercritical mode under different pressure regimes.

Many types of supercritical once through boiler design exist. While some allow complete variable pressure operation, where the pressure across whole boiler is varied (reduced at low loads), others operate at fixed evaporator pressure and thus involve loss of energy for part load operation. Due to requirement of cyclic operation, variable pressure type evaporator system has been adopted in this document.

1.2.2 Water walls design

Supercritical units deploy spiral wall furnace using smooth tubes or vertical wall furnace with rifled tubes. Spiral wall furnace increases the mass flow per tube by reducing the number of tubes needed to envelop the furnace without increasing the spacing between the tubes. It also leads to uniform heat absorption in each tube rendering the spiral wall system less sensitive to changes in the heat absorption profile in the furnace. However, it involves a complex support structure and is relatively difficult to construct and maintain.



The vertical water wall design uses rifled tubing for improved cooling effect with uniform temperature across the walls and is also operating satisfactorily. Its advantage lies in ease of construction and maintenance. Keeping in view the fact that various manufacturers have standard water wall configurations which are proven, both the options viz. spiral and vertical tube designs have been included.

1.2.3 **Boiler start up circulation systems**

Supercritical boiler starts operating in the once through mode beyond a particular minimum load of say 30 to 40 %. Below this load, it operates in the circulation mode and needs a separator and circulation system for water steam separation; the separated water is circulated back to the boiler. Generally, two types of circulation systems are in use. In one of the systems, separated water from the separator is led to the deaerator/ condenser and is circulated to the feed water system through boiler feed pump. This system is simple and relatively inexpensive but involves loss of heat from boiler during cold start-up. In other system a circulation pump is provided to circulate the water from separator directly to the economizer. This prevents heat loss from boiler during cold start-up but adds to cost. Both systems have also been provided in some of the supercritical units to improve reliability. Other proven standard systems for boiler startup drain circulation system are also acceptable.

An alternate drain connection to main condenser has also been envisaged to enable start up of steam generator even when the Start up drain recirculation pump is not in service and for initial flushing of boiler to achieve water/ steam quality.

1.2.4 **HP turbine extraction**

In the sub-critical units upto 500 MW, the highest pressure extraction in the regenerative feed heating cycle is from the HP Turbine exhaust. This conventional design with highest feed water extraction from CRH line is able to achieve a final feed water temperature of about 255⁰C. Designs with extraction from HP turbine are available leading to increased final feed water temperature of about 290⁰C or higher. The higher feed water temperature due to HP extraction leads to a marginally better turbine cycle heat rate. It also involves additional heaters. Keeping in view the advantages of higher efficiency, design with HP turbine extraction has been adopted.

1.2.5 **Boiler feed pump configuration**

A number of configurations viz. 2x50% TDBFP+2x30% MDBFP, 2x50% TDBFP+1x50% MDBFP, 2x50% TDBFP+1x30% MDBFP, 3x50% MDBFP are in use for boiler feed pumps in large size units. The normal practice being followed in the country for 500 MW units is to provide 2x50 % turbine driven Boiler feed pumps (TD-BFP) and 1x50 % motor driven BFP (MD-BFP). The above configuration has the advantage for having same pump for both TD-BFP and MD-BFP leading to interchangeability of spares etc. and better



inventory management. For large size supercritical units also, the same configuration i.e. 2x50 % TD-BFP and 1x50 % MD-BFP has been adopted. Alternate provision of 3x50% MDBFPs has also been suggested. However, this shall be resulting in increased auxiliary power consumption and reduced net unit output.

1.2.6 Design pressure of HP heaters and feed water piping

In case of sub-critical units, feed regulating station is generally located at down stream of HP heaters, and HP heaters and feed water piping from BFP discharge to boiler inlet are normally designed for the shut off head condition of BFPs. However, in case of supercritical units, such a design criteria may lead to extremely high design pressure rating for HP heaters and lead to extremely high thicknesses for pipes and heater tube sheet etc. Thus, in supercritical units, feed regulating station is located at upstream of HP heaters and no isolation valve is provided at economiser inlet. The feed water piping and HP heaters are designed as per design pressure of the boiler with provision of pressure relief valves across HP heaters or media operated three way valves are provided at inlet/ outlet of HP heater(s) so as to prevent BFP shut off pressure from being communicated to downstream piping system and HP heaters.

1.2.7 Water chemistry

Unlike the sub-critical units that offer flexibility for water chemistry correction in the boiler (drum), the supercritical units require necessary quality correction of condensate to ensure final steam quality. High chemical concentration in the boiler water and feed water cause furnace tube deposition and allow solids carryover into the superheater and turbine. Further, dissolved oxygen attacks steel and rate of attack increases sharply with rise in temperature. Accordingly, water chemistry of boiler feed water is maintained using combined water treatment (oxygen dosing and ammonia dosing in condensate and feed water system). Oxygenated treatment (OT) using high purity DM water minimizes corrosion and flow accelerated corrosion (FAC) in the feed water train. Provision for dosing of ammonia and hydrazine (all volatile treatment) is also made during start up and chemical excursions. Further, the units are also provided with 100 % condensate polishing units to achieve requisite condensate quality to the regenerative feed heating systems.

1.2.8 ID fan selection

Normal practice in the country has been to provide radial type Induced Draught (ID) fans for upto 500 MW unit size as radial fans are considered more reliable specially under conditions of high dust loadings (and consequent high wear of fan). However, radial fans of high capacity (for 660/800 MW unit size) may not be available and hence axial type variable pitch ID fans have been adopted. These are more efficient and lead to considerable power savings. Also with considerable improvements in ESP performance, problems of fan wear etc. are not expected to be significant.



1.2.9 **Materials**

High steam pressure and temperature parameters adopted in supercritical boilers require use of improved materials to withstand the severe operating conditions. Gas side corrosion & erosion and steam side scaling and exfoliation are some of the major issues in material selection for coal-fired boilers. Higher temperature leads to creep, high temperature oxidation and accelerated attack of materials due to the presence of aggressive corrosive species, such as sulphur and chlorine, in the coal.

Ferritic, austenitic, or nickel-based alloy with mechanical strength at high temperatures are used in supercritical boilers. Materials being used are T11, T12, T22, T23, T/P91, T/P92, TP-304H, TP-347H and super-304H or equivalent. The relative use of these materials for various surfaces depends on the steam parameters adopted and also on design philosophy of the manufacturer. The high temperature superheater sections normally require advanced materials; however use of advanced materials in other sections can provide design flexibility (e.g., thinner piping/headers for cycling service), though they may not be essential in those areas. Thus sufficient flexibility has been provided for choice of materials for various equipments/ sections and piping to enable design freedom to the manufacturers.



CHAPTER - 2

OPERATING CAPABILITY OF PLANT

- 2.1** The plant shall be designed to operate as a base load station and shall have a design life of minimum twenty five (25) years. However, continuous operation under two shift and cyclic modes during certain periods is also envisaged. The design of the plant equipment and control system would permit participation of the plant in automatic load frequency control. The major operating capabilities for the unit(s)/ plant are envisaged as under:
- 2.1.1** Operate continuously with turbine under VWO condition with rated steam parameters, specified rated condenser pressure and 1% cycle make up.
- 2.1.2** Sliding pressure/ modified sliding pressure operation from rated load down to 40% of rated load. The modified sliding pressure operation shall comprise of constant pressure operation from rated load to approximately 90% of rated load and then sliding pressure operation down to 40% of rated load. At any operating load upto 100% rated load, the turbine shall be capable to achieve an instantaneous increase in turbine output by 5% of the corresponding load, by opening turbine control valves/ overload valves wide open.
- 2.1.3** The plant shall have adequate provision for quick start-up and loading of the units to full load at a fast rate.
- 2.1.4** Operate continuously with all HP heaters out of service with maximum specified cooling water temperature, 1% cycle make up and normal auxiliary steam requirement being tapped from cold reheat line, to generate maximum output without over stressing turbine components. The power output of the unit under this operating condition shall not be less than the rated output (660 or 800 MW, as applicable).
- 2.1.5** In case of sudden reduction in demand (load throw off), the unit should get safely unloaded and stabilized for operation at house load with HP- LP bypass open to required capacity.
- 2.1.6** Operate continuously at rated output (660 or 800 MW, as applicable) under rated steam conditions, specified worst condenser pressure, 1% cycle make-up and 47.5 Hz grid frequency.
- 2.1.7** The design of the plant equipment and control system would permit participation of the plant in automatic load frequency control.
- 2.2** Steam generator, turbine generator and auxiliaries shall be designed to cater to the above operating conditions with adequate margin as per standard practice prevailing in the fossil fired power plants.



CHAPTER - 3

GENERAL TECHNICAL REQUIREMENTS

- 3.1 All equipment, systems and work covered herein shall comply with all latest statutes, regulations and safety codes, as applicable in the locality where the equipment will be installed.
- 3.2 The design of Steam Generator shall meet or exceed all the requirements of latest editions of Indian Boiler Regulations (IBR). Any other standard acceptable to IBR can also be considered, provided that the requirements of that standard are equivalent or more stringent than the IBR requirements.
- 3.3 The turbine generator shall comply with general requirements and standards of latest versions of IEC-45 and 46, IEEE-122, IEC-34-1, IEC-34-3 or their approved equivalents.
- 3.4 The design, construction and testing of all equipment, facilities, components and systems shall be in accordance with latest version of relevant standards and codes issued by Bureau of Indian Standards (BIS) and/or reputed international standards and codes. However, in the event of any conflict between the requirements of the international standards or codes and the requirements of the BIS standards or codes, the more stringent of the two shall be adopted. Complete design including pressure parts, piping, valves and fittings shall meet or exceed all the requirements of the latest versions of Indian Boiler Regulations (IBR).
- 3.5 The various parts or components or assemblies of equipment and systems shall be of proven materials with well established physical and chemical properties appropriate to the service as intended.
- 3.6 All materials, components and equipment shall be tested at all stages of procurement, manufacturing, erection, commissioning as per comprehensive Quality Assurance Programme to be agreed mutually between the purchase and the equipment supplier.
- 3.7 Noise level for the continuously operating equipment shall not be more than 85 dBA at a distance of 1 metre and at a height of 1.5 metre from any equipment except in case of Turbine – Generator. Noise level for Turbine-Generators shall not exceed 90 dBA. For short term exposure, noise levels shall not exceed the limits as stipulated in the Occupational Safety & Health Administration (OSHA) Standard.
- 3.8 Areas where a potential flammable atmosphere may exist shall be classified in accordance with the provisions of latest version of relevant IS. Certified equipment shall be used in the designated hazardous areas. To the extent practicable, equipment requiring operator's attention and/or electrical equipment shall not be installed in hazardous areas.



- 3.9 All power cycle pumps shall comply with the latest applicable recommendations of Hydraulic Institute Standards (U.S.A.) or approved equivalents.
- 3.10 Stand-by equipment of all the auxiliaries which have direct impact on operation and safety of the plant shall be designed for auto start up, on failure of running equipment with minimum time delay and without runback on unit load.
- 3.11 The equipments and auxiliaries shall be suitable for continuous operation in the frequency range of 47.5 Hz to 51.5 Hz.
- 3.12 Wherever oil coolers for any equipment are provided, these shall be of 3x50% or 2x100% capacity to facilitate cleaning without shutting down the equipment. All coolers/jackets shall be designed to take care of the operating pressure of the cooling medium.
- 3.13 The turbine generator shall be provided with electronically controlled governing system with appropriate speed/ load characteristics to regulate the frequency. The governor shall have a droop of 3 to 6%.



CHAPTER - 4

LAYOUT CONSIDERATIONS

- 4.1** The broad salient features of the layout arrangements of various equipment in the main plant building housing the turbine- generator and its auxiliaries and steam generator area are given as hereunder:
- 4.1.1 The arrangement of the turbine- generator in the main plant building shall be of longitudinal type. The boiler centre line shall be the same as that of TG condenser as far as possible. Unit pitching distance between centre lines of two boilers shall be in the range 110- 135m for 660 MW units and 125- 150 m for 800 MW units. The column spacing of main plant building may be about 10 m.
- 4.1.2 The conventional arrangement of AB, BC and CD longitudinal bays with D row as first row of boiler columns shall preferably be adopted. The width of AB bay shall be about 36m when TDBFPs are located at operating floor in AB bay and about 30m when TDBFPs are not located as above. The coal mills shall be located on two sides of the boiler and width of the mill bunker building on each side shall be such that adequate space is available for operation and maintenance of coal mills. Alternatively, front/ rear mill arrangement shall also be acceptable subject to feasibility of the layout. In case of front mill arrangement, suitable provisions shall be made to prevent coal dust entry in the TG area.
- 4.1.3 A clear walkway of 1200mm (min) shall be ensured between the mills / its foundation / mill reject vessel edge and inner face of mill bay column. Raw coal bunker shall be circular in shape.
- 4.1.4 Two transverse bays at 0.0 m elevation equivalent to minimum area of 600m² shall be provided for unloading and maintenance at one end of main plant building. One additional bay shall be provided between two units for maintenance at ground floor. Alternatively, two transverse bays may be provided between two units for unloading and maintenance with one bay on one end of the building for maintenance at ground floor. Further, a minimum lay down area of 600 m² per unit with EOT crane approach shall be kept on the operating floor.
- 4.1.5 TDBFPs shall be located at operating floor/ ground floor in AB/BC bay and MDBFP shall be located at ground floor or mezzanine floor.
- 4.1.6 The location of control room (common for two units) shall be towards BC bay in between the two units at the operating floor level. The control equipment room shall be located adjacent to control room and at mezzanine floor as per the requirement.



- 4.1.7 There shall be no regular basement floors in main plant building and mill bunker bay building. Also, the local pits/trenches in main plant building/ mill bunker bay building/ boiler/ ESP area shall be avoided as far as possible.
- 4.1.8 The deaerator shall be located in the BC bay at an appropriate elevation so as to meet the NPSH requirement of boiler feed pumps. Horizontal HP heaters and LP heaters shall also be located in BC bay with space provision for tube/ shell withdrawal.
- 4.1.9 Clear walk ways of minimum 1.5 m width at all the levels along A & B row shall be provided in the main plant building. For interconnection with service building, walk way of about 3.0 m width shall be provided along 'B' row of main plant building.
- 4.1.10 For EOT crane maintenance, through walkway of minimum 500mm width (without hindrance) shall be provided along A row and B row rails at crane girder level. Approach to the crane through cage/ rung ladders shall be provided at least at two places from the operating floor level.
- 4.1.11 Interconnecting walkways (minimum 1.5m clear width) between main plant building and boiler (on either side of boiler in case of side mill arrangement) at ground, mezzanine, operating and deaerator floor levels shall be provided. Also, inter-connecting platform (minimum 1.2 m clear width) between boiler and coal bunker building at mill maintenance floor level, feeder floor level, tripper floor level and roof of mill bay (if applicable) shall be provided. Number of interconnecting platforms between boiler and coal bunker building for each level/ floor specified above shall be two (2) numbers on each side of Boiler i.e. four (4) numbers per floor in case of side mill arrangement and two (2) numbers per floor for front/ rear mill arrangement.
- 4.1.12 Steam turbine, generator (except stator), BFPs and other equipments located in the turbine hall shall be accessible by the EOT crane(s) for their handling during maintenance and overhauling. For all other equipment/ components located in the main plant building, suitable handling arrangement viz. cranes/ chain pulley blocks/ monorail hoists etc. as required shall be provided for the maintenance and overhauling.
- 4.1.13 Facility shall be provided for handling of condenser water box to enable maintenance and withdrawal of condenser tubes. Alternatively, condenser water box with hinge arrangement may be provided. Rolling shutter(s) or removable sheeting between 'A' row columns alongwith extended platform as necessary shall be provided to facilitate condenser tube withdrawal or removal of condenser mounted LP heater(s), if applicable.
- 4.1.14 Facility of crane/ chain pulley block/ monorail hoist etc. shall be provided alongwith provision of space for maintenance/ overhauling/ handling/ removal of equipment such as mills, pumps, fans, motors, heaters, heat exchangers, and handling of APH baskets and coils of economizer and SCAPH etc.



- 4.1.15 Layout of facilities and equipment shall allow removal of generator transformers, station transformers and unit auxiliary transformers without disturbing structure, equipment, piping, cabling, bus ducts etc. routed in the area.
- 4.1.16 Clear approach width of minimum 10m with clear height of 8m shall be provided at the front and rear of ESP.
- 4.1.17 Trestles to be provided for routing of cables, pipes etc. shall have a clear height of 8.0m in main plant area, at road/ rail crossings so as to clear the road spaces/ railway lines, approach to maintenance bays of various buildings. A walkway with hand rails and toe guards of 600mm (minimum) width shall be provided all along length of the trestle for maintenance of cables and pipes. Ladders for approach to these walkways shall be provided near roads, passage ways at suitable locations.
- 4.1.18 Floor drains shall be provided at all floors and drain discharge pipes shall be properly sized taking into account the fire water sprinkler system wherever provided.
- 4.1.19 Valves shall be located in accessible positions. All piping shall be routed at a clear height of minimum 2.2 m from the nearest access level for clear man movement. Best engineering practices shall be adopted for keeping the minimum clear working space around equipment and clear headroom within main structures and cable trays etc.
- 4.1.20 Fire water pipes in main plant area may be routed in trenches filled with sand and covered with pre-cast RCC covers.
- 4.1.21 The safety requirements as per the Factories Act, Rules/ Regulations made under Indian Electricity Act 2003 and other applicable codes/standards etc. shall be observed while developing the layout.
- 4.1.22 While developing the layout, all fresh air ventilation louvers shall be considered 1000 mm from floor level and directed downwards at an angle. Ventilation fans on AB bay roof shall be staggered and shall not be near the centre line of turbine- generator set. Air washer units could be located at outside TG bay on 'A' row side and in BC bay on 'B' row side.
- 4.1.23 As per requirement of MOE&F, the space provision shall be kept for installation of flue gas desulphurisation (FGD) system in future, if required.
- 4.1.24 Layout of the buildings shall be developed considering TAC requirements for fire escape. Adequate fire escape staircases shall be provided in main plant building with fire doors at each landing. Each equipment room shall be provided with alternate exits in case of fire/ accidents as per requirements of Factory Act and statutory bodies / Insurance companies.
- 4.1.25 Each unit shall be provided with one passenger elevator in TG hall and one passenger cum goods elevator in the boiler area.



CHAPTER 5

PERFORMANCE GUARANTEES

5.1 General Requirements

- 5.1.1 The equipment shall meet the ratings and performance requirements stipulated for various equipment. The guaranteed performance parameters shall be without any tolerance values and all margins required for instrument inaccuracies and other uncertainties shall be deemed to have been included in the guaranteed figures.
- 5.1.2 All the guarantees shall be demonstrated during functional guarantee/acceptance test. The various tests which are to be carried out during performance guarantee/acceptance test are listed in this chapter. The guarantee tests shall be conducted at site on each unit individually.
- 5.1.3 All instruments required for performance testing shall be of the type and accuracy required by the code(s) and prior to the test these shall be calibrated in an independent test Institute. The protecting tubes, pressure connections and other test connections required for conducting guarantee test shall conform to the relevant codes.
- 5.1.4 Detailed Performance Test Procedure to be furnished shall contain the following:
- i) Object of the test.
 - ii) Various guaranteed parameters & tests as per contract.
 - iii) Method of conductance of test and test code.
 - iv) Duration of test, frequency of readings & number of test runs.
 - v) Method of performance calculation.
 - vi) Correction curves.
 - vii) Instrument list consisting of range, accuracy, least count, and location of instruments.
 - viii) Scheme showing measurement points.
 - ix) Sample calculation.
 - x) Acceptance criteria.
 - xi) Any other information required for conducting the test.
- 5.1.5 In case during performance guarantee test(s) it is found that the equipment/system has failed to meet the guarantees, all necessary modifications and/or replacements shall be carried out to make the equipment/system comply with the guaranteed requirements & the same shall be demonstrated by conducting another performance guarantee test at no extra cost to the purchaser. However, if the contractor is not able to demonstrate the



guarantees, even after the above modifications/ replacements within ninety (90) days or a reasonable period allowed by the purchaser, after the tests have been completed, the purchaser will have the right to either of the following:

i) *For Category-I Guarantees*

Reject the equipment/ system/ plant and recover the payment already made

OR

Accept the equipment/ system/ plant after levying Liquidated Damages as stipulated. (Amount of LD to be specified by the purchaser based on unit size, coal cost etc.)

ii) *For Category-II Guarantees*

Reject the equipment/ system/ plant and recover the payment already made. Conformance to the performance requirements under Category-II is mandatory.

iii) *For Category-III Guarantees*

Reject the equipment/ system/ plant and recover the payment already made.

OR

Accept the equipment/ system after assessing the deficiency in respect of the various ratings, performance parameters and capabilities and recover amount equivalent to the damages.

5.2 Guarantees Under Category-I

The performance guarantees which attract liquidated damages are as follows:

- 5.2.1 Efficiency of the steam generator at 100% TMCR with zero make up while firing the design coal at rated steam parameters, rated coal fineness and rated excess air.
- 5.2.2 Efficiency of the steam generator at 80% TMCR with zero make up while firing the design coal at rated steam parameters, rated coal fineness and rated excess air (**for reference**).
- 5.2.3 Steam generating capacity in T/hr. of steam at rated steam parameters at superheater outlet and rated steam temperature at reheater outlet (with any combination of mills working as per purchaser's discretion) with the coal being fired from within the range specified.
- 5.2.4 Turbine Cycle Heat Rate in kcal/kWh under rated steam conditions, design condenser pressure with zero make up at 100% TMCR load.



5.2.5 Turbine Cycle Heat rate in kcal/kWh under rated steam conditions, design condenser pressure with zero make up at 80% TMCR load (**for reference**).

5.2.6 Continuous TG output at 105% TMCR load under rated steam conditions, design condenser pressure with zero make-up.

Note: The condenser pressure measurement while conducting the guarantee tests from clause 5.2.4 to 5.2.6 above shall be measured at 300 mm above the top row of condenser tubes.

5.2.7 ¹Pressure drop across terminal points of condenser cooling system with on-line condenser tube cleaning system in operation.

5.2.8 The total auxiliary power consumption for all the auxiliaries of boiler, turbine Generator and turbine cycle equipments required for continuous unit operation at 100% TMCR load under rated steam conditions and at design condenser pressure with zero make-up.

5.2.9 The total auxiliary power consumption for all the auxiliaries of boiler, turbine Generator and turbine cycle equipments required for continuous unit operation at 80% TMCR load under rated steam conditions and at design condenser pressure with zero make-up (**for reference**).

5.3 Guarantees Under Category-II

5.3.1 It shall be guaranteed that, with one field out of service in each stream, the particulate emission from ESP at TMCR load and design coal firing shall not exceed 50 mg/Nm³ or stipulated requirement of MOEF's in this regard, whichever is more stringent. The corresponding ESP efficiency shall be worked out.

5.3.2 It shall be guaranteed that maximum total NO_x emission from the unit will not be more than 260 grams of NO_x (from thermal as well as fuel) per giga joule of heat input to the boiler at 6% O₂ level during the entire operating range of steam generator for the range of coals specified or as per MOEF's requirement in this regard (if applicable) whichever is more stringent.

5.4 Guarantees Under Category-III

The parameters/ capabilities to be demonstrated for various systems/ equipments shall include but not be limited to the following:

5.4.1 Run back capabilities

The automatic runback capability of the unit (boiler- turbine-generator) on loss of critical auxiliary equipment (such as tripping of one ID /FD /PA fan/ BFP etc.) shall be demonstrated ensuring smooth and stable runback operation.

¹ Applicable in case CW pumps are not included in scope of BTG system.



5.4.2 Start up time (for one unit only)

Start-up time (upto full load), and loading capabilities for the complete unit (boiler, turbine and generator together) for cold start, warm start and hot start conditions as agreed shall be demonstrated, ensuring that the various turbine operational parameters like vibration, absolute and differential expansion, eccentricity and steam metal temperature mismatch etc. are within design limits.

5.4.3 Rate of change of load and sudden load change withstand capability

The capability of boiler-turbine-generator in regard to ramp rate and step load change as specified shall be demonstrated.

5.4.4 Mill capacity at rated fineness

Performance testing shall be done on coal mills towards establishing the specified capacity at the rated fineness, applying corrections for the variation in coal characteristics i.e., HGI (Hardgrove Grindability Index) and total moisture. The test shall be demonstrated on 50% of the installed coal pulverizers (of Purchaser's choice) of each Steam Generator at 100% mill loading with the originally installed grinding elements in nearly worn-out condition or at the end of guaranteed wear life of grinding elements, whichever is earlier. Capacity test shall be demonstrated at the following conditions occurring simultaneously during testing:

i) Coal fineness	Not less than 70% through 200 mesh and not less than 98% through 50 mesh screen.
ii) Test coal	Any available coal from the specified range with coal sampling done as per ISO 9931.

In case the guaranteed capacity of coal pulverizers as stated above are successfully demonstrated, remaining coal pulverizers of corresponding steam generator will also be considered to have successfully met the above capacity guarantee requirement. However, in the event of any of the coal pulverizers not meeting the guarantee test, all the coal pulverizers of corresponding steam generator will have to be tested to demonstrate guaranteed capacity.

5.4.5 Life of mill wear parts

Life of mill wear parts, in hours of operation, for the entire range of coal characteristics specified shall be demonstrated.



5.4.6 **Electrostatic precipitator**

- i) The ESP air in leakage shall not be more than 1% of total gas flow at ESP inlet at the guarantee point condition and shall be demonstrated.
- ii) The maximum pressure drop through the ESP at the guarantee point flow condition shall not exceed 25 mmwc and shall be demonstrated.
- iii) Uniformity of the gas distribution in the various streams and inside the casing shall be demonstrated as per specified/ quoted value.

5.4.7 **No fuel oil support above 40% BMCR load**

It shall be demonstrated that oil support for flame stabilization shall not be required beyond 40% of BMCR load when firing the coals from the range identified. It shall also be demonstrated that with any combination of mills/ adjacent mills in service, the steam generator shall not require any oil firing for stable and efficient boiler operation at and above 40% BMCR load.

5.4.8 **Performance characteristics of fans**

Satisfactory operation of FD, ID and PA fans without undue noise and vibration while operating in isolation or in parallel with other fans shall be demonstrated at site.

5.4.9 **Steam temperature imbalance**

It shall be demonstrated at SH and RH outlets (in case of more than one outlet) that the temperature imbalance between the outlets does not exceed 10⁰ C under all load conditions.

5.4.10 **SH and RH tube metal temperature**

It shall be demonstrated that superheater and reheater tube metal temperature at critical locations remain within maximum tube metal temperature limits as per design of the OEM under various load conditions (i.e. 100%, 80%, 60% & 50%).

5.4.11 **Superheater and reheater attemperation system**

It shall be demonstrate that the spray water flow of SH attemperation system does not exceed 8% of main steam flow, at superheater outlet, while firing any coal from within the range specified with HP heaters in service while maintaining the rated SH outlet steam temperature at all loads upto and including BMCR. It shall also be demonstrate that the RH temperature is maintained at the rated value without any spray water requirement under normal operating conditions.



5.4.12 Furnace exit gas temperature (FEGT)

It shall be demonstrated that maximum furnace exit gas temperature (FEGT) shall be minimum 60 deg C below the minimum initial deformation temperature (IDT) of ash. A comprehensive thermal performance test (TPT) shall be conducted for this purpose on one unit. FEGT shall be demonstrated through such TPT by indirect measurement.

5.4.13 Air heater air in leakage

It shall be demonstrated that the air-heater air-in-leakage after 3000 hours of steam generator operation does not exceed the specified/ quoted values.

5.4.14 Equipment cooling water system

- i) Inlet and outlet temperatures on the primary and secondary side of the plate type heat exchangers as per design shall be demonstrated at site.
- ii) Pressure drop across plate type heat exchanger on primary and secondary side cooling water circuits shall be demonstrated at site.
- iii) Satisfactory operation of primary side DMCCW pumps and secondary side cooling water pumps (as applicable) without undue noise and vibration while operating in isolation or in parallel with other pumps shall be demonstrated at site.

5.4.15 Generator excitation system

The performance of generator excitation system as specified shall be demonstrated.

5.4.16 Steam condensing plant

- i) The value of design condenser pressure, to be measured at 300 mm above the top row of condenser tubes, shall be demonstrated under VWO condition, 1% make-up, design CW inlet temp. and CW flow. The condenser vacuum shall be measured with a vacuum grid utilizing ASME basket tips.
- ii) Temperature of condensate, at outlet of condenser, shall be demonstrated to be near to saturation temperature corresponding to the condenser pressure at all loads.
- iii) Oxygen content in condensate at hotwell outlet shall not exceed 0.015 cc/litre over 50-100% load range and shall be determined according to calorimetric Indigo-Carmine method.
- iv) Air leakage in the condenser under full load condition shall not exceed more than 50% of design value taken for sizing the condenser air evacuation system.



- v) When one half of the condenser is isolated, condenser shall be capable of taking at least 60% T.G. load under TMCR conditions.
- vi) The design capacity of each vacuum pump in free dry air under standard conditions at a condenser pressure of 25.4 mm Hg (abs) and sub cooled to 4.17⁰C below the temperature corresponding to absolute suction pressure shall be demonstrated. Correction curves for establishing the capacity at site conditions shall also be furnished.
- vii) The air and vapour mixture from air cooling zone of condenser shall be 4.17⁰C below the saturation temperature corresponding to 25.4 mm Hg (abs) suction pressure. Correction curves for establishing the same at site conditions shall also be furnished.
- viii) ²Pressure drop across terminal points of condenser cooling system with on line condenser tube cleaning system in operation.

5.4.17 Feed water heaters and deaerator

The following parameters shall be demonstrated:

- i) TTDs and DCAs of feed water heaters shall be demonstrated as per guaranteed heat balance diagram for 100% TMCR condition.
- ii) Outlet temperature from final feed water heater(s).
- iii) Difference between saturation temperature of steam entering the deaerator and temperature of feed water leaving the deaerator shall be demonstrated as per guaranteed heat balance diagram for 100% TMCR condition.
- iv) Continuous and efficient operation and performance of feed heating plant without undue noise and vibrations at all loads and duty conditions.

5.4.18 HP & LP bypass system capabilities

The design capacity of HP/ LP bypass system shall be demonstrated. Further, the HP & LP bypass system should satisfy the following functional requirements under automatic interlock action. It should come into operation automatically under the following conditions:

- i) Generator circuit breaker opening.
- ii) HP & IP stop valves closing due to turbine tripping.
- iii) Sudden reduction in demand of external load (load throw off).

² Applicable in case CW pumps are included in scope of BTG system.



Under all above conditions, while passing the required steam flows as per the relevant heat balances, the condenser should be able to swallow the entire steam without increasing the exhaust hood temperature and condenser pressure beyond the maximum permissible values. The same shall be demonstrated.

5.4.19 Power cycle pumps

Satisfactory operation of BFPs and CEPs without undue noise and vibration while operating in isolation or in parallel with other pumps shall be demonstrated at site.

5.4.20 Condenser on load tube cleaning system

Life of sponge rubber balls and number of balls lost during 1000 hours of plant operation as agreed in contract shall be demonstrated.

5.4.21 Automatic on-line turbine testing (ATT) system

On-load testing of turbine protective equipments without disturbing normal operation and keeping all protective functions operative during the test shall be demonstrated.

5.4.22 Noise

- i) All the plant, equipment and systems shall perform continuously without exceeding the specified noise level over the entire range of output and operating frequency.
- ii) Noise level measurement shall be carried out using applicable and internationally acceptable standards. The measurement shall be carried out with a calibrated integrating sound level meter meeting the requirement of IEC 651 or BS 5969 or IS 9779.
- iii) Surface sound pressure shall be measured all around the equipment at a distance of 1.0 m horizontally from the nearest surface of any equipment/ machine and at a height of 1.5 m above the floor level in elevation. The average of A-weighted surface sound pressure level measurements expressed in decibels to a reference of 0.0002 micro bar shall not exceed 85 dBA except for:
 - a) Safety valves and associated vent pipes for which it shall not exceed 115 dBA with silencer as applicable.
 - b) Regulating drain valves in which case it shall be limited to 90 dBA.
 - c) TG unit in which case it shall not exceed 90 dBA.
 - d) HP and LP bypass valves operation for which it shall be restricted to 115 dBA.



- e) For air motors it shall not exceed 95 dBA.
- f) For pressure regulation valves & steam generator water drain control valve it shall not exceed 90 dBA.

Corrections for background noise shall be considered in line with the applicable standards.

5.4.23 Condensate polishing plant

- i) Effluent quality at outlet of each vessel at its rated design flow and design service length between two regenerations.
- ii) Pressure drop across the polisher service vessel, as specified, in clean and dirty condition of resin at rated design flow.

5.4.24 Control & Instrumentation system requirements

Performance guarantee tests for closed loop control systems shall be carried out at site to verify the integrated performance of the C&I system and to verify as to whether all the important parameters remain within stipulated permissible limits under all the operating conditions. In case during these tests or otherwise it is observed that the behavior/ response of individual system (drives actuators/ valves etc.) is not satisfactory/ acts as a limitation/ restriction in achieving the permissible limits, all required modifications, rectification etc. shall be made in the C&I system so that the permissible limits can be achieved.

5.4.25 EOT crane

After assembly and erection of crane at site, the crane shall be subjected to deflection test, overload test, brake test and other tests as per IS 3177.

5.4.26 Elevators

After installation at site, the elevators shall be subjected to the following tests:

- i) Overload test.
- ii) Travel speed and hoist speed checks.
- iii) Drop test.
- iv) Checks for interlocks & safety systems.
- v) Checks for operation from inside the cage.

5.5 Test Codes, Test Conditions etc.

5.5.1 Steam generator efficiency

- i) The steam generator efficiency shall be determined as per the requirements of ASME PTC- 4 (by energy balance method) and other stipulations brought out hereunder.



a) Test loads	100% TMCR and 80% TMCR.
b) Test conditions	Boiler operating at rated steam parameter, excess air, coal fineness and firing design coal.
c) Ambient conditions	27°C dry bulb temperature and 60% relative humidity. The reference air temperature for the efficiency guarantee/ testing shall be taken as 27°C at APH inlet (without consideration of heat credits).
d) No. of readings	Two sets of consistent readings for each of test loads. Average of the test efficiencies based on above two readings for each load shall be considered for evaluation.
e) APH leakages to be considered	Guaranteed or actual whichever is higher.
f) Test duration	Four hours. No soot blowing shall be allowed during the test period or during stabilization period of four hours prior to commencement of the test.
g) Heat credits	No heat credits allowed. The guaranteed steam generator efficiency shall be without any heat credit.

- ii) The guaranteed efficiency shall comply with following limiting parameters with design coal firing:

a) Excess air at economizer outlet at 100% TMCR load	20% (minimum).
b) Corrected flue gas temperature (at 100% TMCR load)	125 ⁰ C or as predicted by the supplier at air preheater outlet whichever is higher.
c) Boiler efficiency loss to be considered due to unburnt carbon	Minimum 1%.

- iii) The following correction curves shall be applicable for performance test of the steam generator:

- a) Ambient air temperature.
- b) Relative humidity of ambient air.
- c) Hydrogen in coal.
- d) Moisture in coal.
- e) Gross calorific value of coal.
- f) Feed water temperature at economiser inlet.

5.5.2 Performance test of ESP

- i) The performance/ acceptance tests shall be carried out in accordance with method-17 of EPA (Environmental Protection Agency of USA) code.



- ii) The following correction curves shall be applicable for performance test of the ESP:
 - a) Inlet flue gas flow.
 - b) Inlet flue gas temperature.
 - c) Inlet dust loading.
 - d) Sulphur content of coal.

5.5.3 Auxiliary power consumption

The unit auxiliary power consumption shall be calculated using the following relationship:

$$P_a = P_u + TL$$

P_a = Guaranteed Auxiliary Power Consumption.

P_u = Power consumed by the auxiliaries of the unit under the test.

TL = Losses of the transformers based on works test reports.

While guaranteeing the auxiliary power consumption, all continuously operating unit auxiliaries shall be included and number of coal mills to be considered in operation shall be as per requirement of design coal.

5.5.4 Performance/ acceptance test for turbine generator

- i) Performance test for the turbine generator set will be conducted in accordance with the latest edition of ASME PTC-6.
- ii) Power consumed by the integral auxiliaries mentioned which is to be deducted from electrical power generated, shall be measured during the performance/ Acceptance Test. Wherever the measurement is not possible, design values of power consumption by an auxiliary shall be considered.
- iii) Corrections to the test results for steam turbine shall be applied as per the correction curves provided. When the system is properly isolated for a performance test, the unaccounted for leakages should not be more than 0.1% of the design throttle flow at full load. However, during the test, if it is found that the unaccounted for leakage is more than 0.1% of design throttle flow at full load, then heat rate will be increased by an amount equal to half the difference between actual unaccounted for leakage expressed as percentage of design throttle flow at full load and 0.1% (allowed by the code). In case excessive leakage is visible in the plant area, the source of leakage shall be identified and attended before commencement of the test.
- iv) The tests shall be arranged in a manner that the normal unit operation is not disrupted. Duplicate test runs shall be performed at 100% TMCR and 80 % TMCR loads. The results of corrected heat rate shall agree within 0.25% and average of two shall be considered heat rate achieved.



If they differ by more than 0.25%, additional test run(s) shall be made at the same point until corrected heat rates of atleast two test runs agree within 0.25% and achieved heat rate shall be calculated as average of test run points satisfying the above criterion.

- v) The performance guarantee test shall be carried out after successful completion of trial operation. Ageing allowance shall be applicable during evaluation of PG test results in line with ASME-PTC-6 report 1985 (reaffirmed 1991). Period of ageing shall be considered from the date of successful completion of trial operation to the date of conductance of PG test. In calculating the above factor, any period(s) during which the turbine has not been in operation at a stretch for more than one week shall not be considered.
- vi) The following correction curves shall be applicable for performance test of the turbine generator:
 - a) Main steam temperature.
 - b) Main steam pressure.
 - c) Reheat steam temperature.
 - d) Condenser back pressure.
 - e) Superheater desuperheating spray.
 - f) Generator power factor.
 - g) Generator hydrogen pressure.

The extent of correction admissible for superheater desuperheating spray shall be with reference to the design value considered in the guaranteed heat rate HBD.

5.5.5 Performance test for the condensers

- i) Performance test for design condenser pressure shall be conducted in accordance with latest edition of ASME PTC- 12.2.
- ii) Condenser pressure shall be measured at 300 mm above top row of tubes under VWO conditions, 1% make-up and design C.W. flow & design temperature. The condenser pressure shall be measured with a vacuum grid utilizing ASME basket tips. The grid shall be fitted at 300 mm above top row of condenser tubes.
- iii) Tube plug margin of 5%, as per design condition, shall be considered for condenser performance calculation at design condition.
- iv) The tube side fouling resistance for design condition shall be calculated as per specified cleanliness factor. The tube side fouling resistance for actual test condition shall be measured as per methodology given in ASME PTC 12.2. Alternately, the same shall be calculated using expected actual cleanliness factor appropriately assessed considering the aspect of actual tube cleaning prior to conducting the test.



SECTION-2

STEAM GENERATOR & AUXILIARIES



CHAPTER 6

STEAM GENERATOR

6.1 Type

- 6.1.1 The Steam Generator shall be of single pass (Tower type) or two pass type using either spiral wall (inclined) or vertical plain/ rifled type waterwall tubing.
- 6.1.2 The Steam Generator shall be direct pulverized coal fired, top supported, single reheat, radiant, dry bottom, with balance draft furnace and shall be suitable for outdoor installation. The evaporator of Steam Generator shall be suitable for variable pressure operation from sub-critical to supercritical pressure range.
- 6.1.3 The plants based on indigenous coal may be required to use some proportion of imported coal also. As such, steam generator shall be appropriately designed so that it is suitable for indigenous coal and blended coal with imported coal upto 30% on weight basis.

6.2 Rating of Steam Generator

The Steam Generator shall be designed to cater to duty requirements/rating as specified below:

i)	Steam flow at superheater outlet at boiler maximum continuous rating (BMCR)	1.02 times the steam flow at turbine VWO condition plus continuous auxiliary steam requirement of unit at TMCR, rounded to next integer divisible by 5.
ii)	Steam temperature: a) At superheater outlet b) At reheater outlet	To correspond to HP turbine inlet temperature of minimum 565 ⁰ C [indicative value: minimum 568 ⁰ C]. To correspond to IP turbine inlet temperature of minimum 593 ⁰ C [indicative value: minimum 596 ⁰ C].
iii)	Steam pressure at superheater outlet	To correspond to turbine throttle steam pressure of minimum 247 kg/cm ² (abs) [indicative value: minimum 256 kg/cm ² (abs)].
iv)	Feed water temperature at economizer inlet	287.5±2.5 ⁰ C [or as per optimisation by TG supplier].
v)	Steam generator control range	50% TMCR to 100% BMCR.

Notes:

- a) Pressure drop in reheat steam circuit (cold reheat, hot reheat line & reheater) should not exceed 10% of HP turbine exhaust pressure under all operating conditions including 100% BMCR condition.
- b) The steam temperatures at superheater and reheater outlet(s) shall be guaranteed to be maintained at ±5⁰C of the rated value under all operating conditions within the control range.



6.3 Fuels

6.3.1 Coal

- i) The primary fuel for the Steam Generator(s) shall be coal (coal characteristics of design coal, worst coal, best coal and range of coal for the project to be considered for boiler design).
- ii) The Steam Generator shall be designed to give the guaranteed efficiency when firing the coal having the characteristics for design coal.
- iii) The Steam Generator and its auxiliaries shall also be capable of obtaining the boiler maximum continuous rating (BMCR) when firing the coal having the characteristics for worst coal. The Steam Generator and its auxiliaries shall be designed for efficient and trouble free operation when firing the design, worst and best coals and any of the coals characteristics in between these for complete load range. The Steam Generator and its auxiliaries shall also be capable of giving BMCR rating and meet other operating capabilities, without any trouble and limitations, when firing the coals having the specified range of characteristics.
- iv) Steam Generator and its auxiliaries shall also be capable of obtaining maximum continuous rating when firing with any of the coal within the specified range of coal. System redundancies/ margins on equipment/ auxiliary sizing need not be available under such fuel firing condition unless specifically mentioned otherwise. However, equipments/ systems shall not exceed their safety limits under such firing, and shall not transgress into factors of safety as per specification/ codes.

6.3.2 Fuel oil

The fuel oil (HPS/LSHS/HFO) shall be used for start-up, coal flame stabilization and low load operation of the Steam Generator(s). In addition, the light diesel oil (LDO) firing facilities shall also be provided for cold start up of the steam generator(s). Alternatively, only LDO can be used for start-up, coal flame stabilization and low load operation including cold start-up.

6.4 Salient Design Features and Capabilities

6.4.1 Limiting parameters for steam generator design

The Steam Generator design shall comply with the following limiting parameters with 'design coal' firing, under stipulated ambient air condition i.e. 27^o C temperature and 60 % relative humidity:

i) Excess air at economizer outlet at 100% TMCR load	20% (minimum).
ii) Corrected flue gas temperature (at 100% TMCR load)	125 ^o C or as predicted by the supplier at air preheater outlet (also considering acid dew point) whichever is higher.



6.4.2 Minimum load without oil support for flame stabilization

The design of Steam Generator shall be such that it does not call for any oil support for flame stabilization beyond 40% BMCR load when firing any coal from the range specified, with any combination of mills/ adjacent mills in service.

6.4.3 Loading/unloading pattern and adaptability for sudden load changes/load throw off

i) To match the desired plant operating capabilities, the Steam Generator shall be designed for cyclic/two shift operation. Expected numbers of Steam Generator startups during design life of minimum 25 years are as follows:

a) Cold Start (after shut down period exceeding 72 hours)	150
b) Warm Start (after shut down period between 10 hours and 72 hours)	1000
c) Hot Start (after shut down period less than 10 hours)	4000

ii) Under the above conditions, no portion of the Steam Generator and the associated systems shall be stressed beyond acceptable safe stress and fatigue levels and the design of Steam Generator and its pressure parts shall take care of above without affecting the life of equipment and pressure parts adversely.

iii) Steam generator shall also be capable of satisfactory, stable and safe operation in case of rapid load changes in downward direction due to external disturbances or equipment malfunction. Under such conditions the system shall stabilize itself through proven concepts and controls and within the recommendations of National Fire Protection Association, USA, NFPA-85.

iv) In case of sudden load throw-off, in worst case from 100% BMCR, the Steam Generator shall be capable of automatically bringing down the steam generating capacity to match with HP-LP bypass capacity. Minimum load of Steam Generator to which it can be brought down under such condition, during short turbine outages or export load rejection, with a view to save fuel and reduce heat losses shall be indicated. The boiler design shall ensure balanced draft condition, avoid overheating of reheater tubes and such other conditions that jeopardize the safety and life of boiler.

6.4.4 Operation without high pressure (HP) heaters in service

Steam generator shall be capable of sustained operation with all HP heaters out of operation with generation of at least rated power output by the unit.



6.4.5 Operation with HP and LP turbine bypass system

- i) With HP-LP bypass system in operation, the unit shall be capable of smooth start-up, fast loading & house load operation.
- ii) Steam Turbine trip will call for boiler operation in HP/LP bypass mode. Under this condition, the boiler shall be capable of operating with SH flow corresponding to capacity of HP bypass system and feed water temperature of approximately 140°C at economiser inlet.

6.4.6 Mode of steam generator operation and rate of loading

- i) As mentioned above, the Steam Generators shall be designed for variable pressure operation. Thermal design of Steam Generator and the selection of materials of pressure parts shall be suitable for variable pressure operational modes.
- ii) The Steam Generators shall be designed for minimum rate of loading/unloading mentioned below without compromising on design life of pressure parts:
 - a) Step load change : Minimum $\pm 10\%$
 - b) Ramp rate : Minimum $\pm 3\%$ per minute above 30% load
- iii) The maximum rates of loading/ unloading achievable with Steam Generator offered and the corresponding limiting variations ($\pm\%$) of boiler parameters such as oxygen in flue gas, SH/RH steam temperature, furnace draft, etc. shall be indicated.

6.4.7 Steam generator control range

The automatic outlet steam temperature control range of Steam Generator shall be from 50% TMCR to 100% BMCR for superheater as well as reheater. Under the above control range, the steam temperatures at SH & RH outlets shall be maintained at their rated values within allowable $\pm 5^\circ\text{C}$ temperature variation.

6.4.8 Provision for future installation of FGD system

A flue gas desulphurization (FGD) system may be installed in future to meet the requirements of pollution control. Following provisions need to be kept for this purpose:

- i) Suitability of duct between ID fan and chimney for future interconnection of FGD system with minimum modification.



- ii) The ducting and supporting structure to be designed to take care of future Guillotine damper to be installed between the two tap offs before chimney.

6.4.9 Limits of NO_x emission

- i) The guaranteed maximum NO_x emission (thermal as well as fuel) from the Steam Generator unit shall not exceed 260 grams of NO_x per Giga Joule (GJ) of heat input to the boiler at 6% O₂ level for the range of coals specified or as per MOEF's requirement in this regard (if applicable) whichever is more stringent.
- ii) The above value of NO_x shall not be exceeded during the entire operating range of Steam Generator for the whole range of specified coals.

6.4.10 Capital overhaul of steam generator

The design and materials for various equipments/auxiliaries etc. shall be selected keeping in view capital overhaul of units once in two (2) years, such that no major repairs/replacements, requiring shutdown of the unit, are needed in between the capital overhauls.

6.4.11 Noise level

The equivalent weighted average of sound level for continuously operating equipment measured at a distance of 1.5 m above floor level in each elevation and one meter horizontally from the base of any equipments furnished, expressed in decibel to a reference of 0.0002 microbar, shall not exceed 85 dB(A).

6.4.12 Operational requirement

The Steam Generator(s) shall be designed for the following minimum operational requirements at all loads and for the specified range of coal(s).

i)	Soot blowing frequency	As per OEM's recommendation for characteristics of the coal being fired
ii)	Preferred mill combination	Any combination of mills (without any restriction)
iii)	Max. coal flow unbalances in coal pipes from same mill, from the average	5.0%
iv)	Slagging : a) Burner b) In furnace/ash hopper/ water wall areas	Nil Nil
v)	Maximum permissible reheat spray water flow with rated steam temperature at reheater outlet	3% of steam flow at reheater outlet
vi)	Maximum gas temperature variation across furnace width and depth	30 ⁰ C



vii)	Maximum steam side temperature imbalance in the LHS & RHS at boiler outlet (from the average)	10 ⁰ C
viii)	Minimum load with separator running dry	30-40 % TMCR (As per manufacturer's proven practice)
ix)	Header pressure unbalance (steam side)	6%
x)	Air ingress from furnace bottom Hopper	As per manufacturer's predictions

6.4.13 Safety and relief valves

Boiler Safety valves and relief valves shall have minimum discharge capacities as under:

	Valve	Minimum discharging capacities
i)	Spring loaded safety valves at:	
	a) Separator & superheater	Combined capacity 100% BMCR
	b) Reheater system	Combined capacity 105% of reheater flow at BMCR
ii)	Electromatic relief valves at:	
	a) Superheater outlet	10% BMCR
	b) Reheater outlet	15% BMCR

6.4.14 Steam purity parameters

Steam purity parameters at outlet of the steam generator shall meet requirement of turbine manufacturer and shall generally not be inferior to those indicated below:

- i) Sodium : < 3 ppb
- ii) Chloride : < 3 ppb
- iii) Iron : < 10 ppb
- iv) Silica : < 10 ppb
- v) Cation conductivity : < 0.2 μS/cm

6.5 Specifications of Equipment and Systems

The specified requirements shall be complied for the most stringent conditions resulting either from the range of coals (design/ worst/ best) or from the range of operating conditions specified (like 100% BMCR or HP Heaters out of operation etc.), or from both occurring simultaneously, unless specifically mentioned otherwise.

6.5.1 Steam generator enclosure

- i) Steam Generator enclosure shall form air/gas tight envelope from secondary air and primary air inlet points to chimney inlet.



- ii) The enclosure integral with boiler (except air heaters) shall be formed by water/steam cooled tubes on all the four sides, roof and bottom. The furnace water walls shall be formed using either spiral (helical) wound tubes or vertical plain/rifled tubes. The roof of single pass/tower type boilers could be formed by gas tight metal sheeting of appropriate material.
- iii) The enclosure shall be formed using welded wall construction only. Where use of refractory is unavoidable, 4mm thick steel plate behind refractory shall be provided to form enclosure.
- iv) Any penetration(s) into the steam generator enclosure shall be sealed for gas tight integrity.
- v) The Steam generator enclosure shall be provided with:
 - a) Air cooled observation ports for each oil/coal burner and at various platform levels on all the walls.
 - b) Openings with hinged doors (air/gas tight) in all areas needing access for internal observation/maintenance. Minimum two openings for each area shall be provided.
 - c) Approach platform for each observation port/opening alongwith ladders from nearest platform level.
 - d) Seal plates of stainless steel (type 430) or better corrosion and erosion resistant steel material of minimum 6 mm thickness, all round the furnace bottom, to prevent ingress of air.
- vi) Dissimilar metal welds (DMW) between martensitic and austenitic steels, martensitic and ferrite steel shall be avoided inside the boiler enclosure for the pressure parts, which are exposed to hot flue gases. However, if such DMW are unavoidable, same can be permitted at shop provided manufacturer has previous experience of such DMW and appropriate heat treatment is done after welding.
- vii) In the steam generator enclosure, minimum 1.5 m cavity height shall be provided in between the horizontal banks/ sections of economizer, superheater and reheaters for maintenance purpose.
- viii) No ingress of air from any opening like bottom hopper, soot blower, any manhole or peep hole, ducts etc. shall be considered for sizing of secondary and primary air fans while the same shall be considered for performance predictions.
- ix) Steam generator casing/pent house (as applicable) shall be provided. The casing/pent house design shall ensure:
 - a) Complete enclosure of steam generator including superheater, reheater & economizer headers.



- b) The casing/ pent house and its supporting system shall be capable of taking additional loads due to accumulations of ash upto 300 mm height or actual expected (in between two overhauls of the units), whichever is higher. This additional load is over and above other loads considered for casing design. The ash density for the purpose of ash loading shall be at least 1350 kg/m³.
- c) The pent house shall be provided with arrangement of fans for cooling by supply of fresh air.

6.5.2 Pressure parts

i) *Materials*

The material used for Steam Generator components i.e. boiler pressure parts including boiler tubing, headers, separators, piping, vessels, valves & fittings etc. and other components shall be equal to or better than the following unless specified otherwise:

Design metal temperature	Material
a) Upto & including 400 ⁰ C	Carbon steel to ASME SA-106 Gr. B/C or SA 210 Gr. A1/ Gr. C or equivalent.
b) Upto & including 550 ⁰ C	Alloy steel to ASME SA-335: P-11/P-12/P-22; ASME SA213:T-11/T-12/T22/T23 or equivalent.
c) Upto & including 605 ⁰ C	Alloy steel ASME SA-335/213:P-91/T-91, T-92, or equivalent.
d) Above 605 ⁰ C	Austenitic stainless steel, Super 304H, TP347H or equivalent.

- ii) The design of all pressure parts (tubes, headers, separators, vessels etc.) shall meet the requirements of Indian Boiler Regulations (IBR).
- iii) Design pressure of the steam generator pressure parts shall be at least 1.05 times the maximum operating pressure, or as required by IBR/other international codes, whichever is higher.
- iv) The thickness of the pressure parts (steam and water tubes/headers, separators, pressure vessels etc.) shall be calculated using IBR formulae/factor of safety etc. (and not as per codes/formulae acceptable to IBR). Minimum tube thickness at the bends in no case shall be less than the minimum required tube thickness for the straight tubes. For this purpose appropriate thinning allowance shall be considered while calculating the thickness of the bends. Additional erosion allowance on the calculated tube thickness shall be provided at specific locations as specified.



- v) The working fluid temperature to be considered for design of boiler tubes, headers, separators and other pressure parts upto first stage of attemperation, shall be as maximum predicted/ expected fluid temperature in these pressure parts plus margins as per IBR.

6.5.3 Furnace/ evaporators and water walls

- i) Furnace/ evaporator/ water walls shall comply with following requirements at 100% BMCR or 100% TMCR with all HP Heaters out condition for the range of specified coals, whichever is more stringent:

a)	Net heat input (NHI)/ plan area of furnace	4.75×10^6 kcal/hr/m ² (maximum).
b)	Heat liberation rate	106920 kcal/hr/m ³ (maximum).
c)	Burner zone heat release rate (BZHRR)	1.5×10^6 kcal/hr/m ² (maximum).
d)	Maximum FEGT (MHVT value)	60 ⁰ C below minimum IDT of ash.
e)	Heat input per burner(*)	750×10^5 kcal/hr (maximum).
f)	Furnace cooling factor	2×10^5 kcal/hr/m ² (maximum).
g)	Furnace residence time(**)	2.0 sec. (minimum).
h)	No. of burner elevation being fed from one mill	1 (maximum).
i)	Pressure withstanding capability	+/-660 mmwc (minimum) at 67% yield strength or maximum conceivable head of fans, whichever is higher.
j)	Buckstay spacing	To ensure that its natural frequency is sufficiently away from the flame pulsation frequency.
k)	Buckstay support	Self support from furnace walls. No interconnection with boiler structure shall be allowed.
l)	Furnace Bottom hopper	Design of Boiler and its supporting structure shall be considering 50% ash/clinker loading in furnace bottom hopper and corresponding to ash density of 1350 kg/m ³ . Further, load cells shall be installed in the furnace roof enclosure to give indication of ash build up in the furnace bottom hopper.

(*) Minimum number of coal pulverisers to be provided for each steam generator shall not be less than six (6) for 660 MW unit and eight (8) for 800 MW unit.

(**) Selected furnace residence time shall be "Coal Specific".



ii) *Definition of Acronyms Used in (i) Above*

a) NHI & furnace plan area

1. Net heat input (NHI) or heat available in furnace is obtained by considering the calorific value of the fuel minus the radiation losses, loss due to unburnt combustibles, moisture in air, moisture in fuel, moisture formed by combustion of H₂ in the fuel plus the sensible heat of combustion air (primary plus secondary air), all above 27⁰C.
2. Furnace plan area is the product of furnace width and depth.

b) Burner zone heat release rate (BZHRR)

Burner zone is defined as the centre line distances between the Top and Bottom burner plus 3.05 meters of furnace height. Further, heat input is the input from coal.

c) FEGT (MHVT)

1. FEGT is the furnace exit gas temperature in degree Celsius.
2. MHVT value is the flue gas temperature as measured by a multi shielded high velocity thermocouple (MHVT).

Note: Furnace exit plane shall be defined as the plane, vertical for two pass steam generator and horizontal for single pass (tower type) steam generator, above the furnace nose tip or the plane beyond which the transverse tube pitching is less than 600 mm whichever is positioned first in the flue gas flow path. Further, all the predicted/ guaranteed gas temperature including FEGT indicated shall be the actual MHVT value and not the HVT values.

d) Furnace cooling factor

Furnace cooling factor, in kcal/hr/m², is the ratio of NHI or heat released and available and effective projected radiant heat absorbing surface (EPRS). For arriving at furnace cooling factor the calculated EPRS shall be reduced by at least 10% to account for deterioration of furnace walls surface condition due to fouling/ slagging etc.

e) Furnace residence time

Furnace residence time shall be defined as the residence time of the fuel particles from center line of the top elevation coal burners to the furnace exit plane. For the purpose of residence time the exit plane shall be defined as the horizontal plane at the furnace nose tip for two pass boiler & the horizontal plane at the entry to the radiant superheater/ reheater for single pass/ tower type boiler. Further,



Furnace residence time shall be calculated by dividing the furnace volume between the center line of top coal burner and furnace exit plane by the flue gas volume at mean gas temperature in the above furnace volume.

- iii) Furnace/ evaporator shall be designed for variable pressure operation over 30% to 100% BMCR load range.
- iv) Water/ steam walls shall be of membrane wall construction and shall be made of seamless tubes. Furnace/ evaporator shall be formed using spiral wound/ inclined tubing or vertical plain/ rifled tubing as per the proven practice of the manufacturer for boilers of similar capacity. Irrespective of the type of water wall tubing offered for the evaporator, the design offered shall ensure that no readjustment of tube mass flow is required during entire operating regime of the steam generator for complete range of specified coals. In case such readjustment becomes necessary over a period of five years from the date of successful completion of initial operation of respective steam generator, the same shall be carried out by the supplier. Appropriate time required for readjustment and period of shut down shall be indicated.
- v) Elevation of Furnace Bottom Hopper shall be at least 10.25 m above grade level for wet bottom ash handling system and opening of bottom hopper shall be 1.10 m (minimum) wide.
- vi) A minimum allowance of 0.6 mm over and above the calculated thickness as per IBR shall be provided for entire water wall. An additional tube thickness of 1.0 mm over and above the tube thickness of water wall tubes calculated as per above shall be provided on all water wall tubes coming within a radius of one meter around each wall blower to guard against premature tube failure due to soot blowing steam erosion.
- vii) Flame impingement on steam/ water walls is not permitted.
- viii) Maximum allowable tube skin temperature for evaporator section shall be 40⁰C below oxidation limit for tube metal.
- ix) Headers shall be located external to gas path and shall be completely drainable. If locating headers in gas path becomes unavoidable, then suitable erosion shields/ protectors must be provided.
- x) Minimum 10 mm dia. wear bars of suitable wear resistant material shall be welded along the full length of first 40 tubes of inclined water wall tubes of S-panel of bottom hopper from each corner up to hopper opening or adequate additional thickness shall be provided to take care of erosion.



- xii) Minimum tube thickness at the bends in no case shall be less than the minimum tube thickness for the straight tubes calculated in the manner described above. For this purpose appropriate thinning allowance shall be considered while calculating the thickness of the bends
- xiii) In case water wall orifice are provided, these should be supplied with indexing holes and index pins.
- xiii) *Other Provisions*
 - a) Provision for future installation of additional soot blowers shall be made in the furnace so that after commissioning of each unit, the same can be installed, if the operational experience warrants the same. For this purpose the furnace construction shall preferably be provided with wall box openings. Necessary space provision in layout for providing approach and platform for future soot blowers shall be kept in the original design so that same can be installed whenever the future soot blowers are required. The loads for these platforms shall be considered in the boiler structure design.
 - b) Erosion resistant shields shall be provided for tubes/ header affected by gas impingement/ laning effects (e.g. in a between SH/RH, economizer and furnace walls openings for economizer bypass etc.).
 - c) Tapping points at five levels shall be provided for furnace vacuum monitoring (in addition to routine monitoring).
 - d) All around seal plates of stainless steel type 430 or better (6-mm thick minimum) welded to furnace hopper for sealing against air ingress.
 - e) Panel to panel welding in burner zone may be avoided to maximum possible extent.
 - f) Evaporator section shall be provided with sufficient number of temperature probes for metal temperature measurement as per standard and proven practice of the OEM. A suggested criterion for the same is to provide one temperature probe for every three consecutive tubes.
 - g) Stainless steel expansion markers/ indicators shall be provided on all four furnace walls to monitor thermal expansion and predicted thermal expansion at different levels shall be indicated.

6.5.4 Steam separator(s)

- i) Design Code IBR.



- ii) Design Temperature Maximum fluid temperature plus margin as per IBR.
- iii) Design Pressure 1.05 times the maximum operating pressure or as required by IBR/ other international codes, whichever is higher.

6.5.5 Boiler startup recirculation and drain water system

- i) Boiler start-up recirculation & drain system shall be provided with start-up drain re-circulation pump and alternate drains shall be led to atmospheric flash tank or directly to turbine condenser. 2x50% condensate pumps shall be provided for pumping the atmospheric flash tank condensate to turbine condenser. Necessary control valves shall be provided in the condensate line for maintaining the level in the flash tank/ drain receiving vessel.
- ii) The start-up recirculation & drain system shall comply with following design requirements:
 - a) Designed for fast start-up with and without the recirculation pumps and cyclic load operation of Steam Generator.
 - b) Designed for maximum possible recirculation & drain flow under all possible normal, abnormal, upset and accidental conditions. The drain piping, valves, flash tank, drain receiving vessel and condensate pumps shall also be sized to cater to this.
 - c) Start up recirculation & drain piping and its supports shall be designed to take care of excessive vibration, which may result from two phase flow conditions, if it occurs.
 - d) The start-up drain re-circulation pumps shall be of proven design. Boiler start-up drain recirculation pumps and their motors shall meet the following requirements:

1. Number of pump	1x100% (sized for maximum flow as specified above).
2. Type of pump	Glandless zero leakage type with overhung impeller.
3. Motor specification	Submerged type with wet stator with water coolers. Motor for steam generator start up recirculation pump shall be a wet motor, specifically designed by the pump manufacturer for the application and shall be as per the standard adopted by the pump manufacturer. Motor windings shall be of non-hygroscopic material and shall be designed to withstand continuous water pressure & temperature variation.



	<p>The insulation shall have sufficient dielectric strength to withstand rated phase to earth voltage in slot portion and phase to phase voltage in end windings. The insulation material shall not have any tendency for plastic deformation even under extreme operating condition like the conductor temperature, mechanical forces, vibrations etc.</p> <p>The cooling circuit shall be provided with suitable device to guard against any rise in pressure. Power & instrumentation leads shall be taken out of the motor through water tight sealing glands & shall be run in flexible metal conduits or metal cable sheathing along the length of the pump body.</p> <p>The design of the seals shall allow for effects of differential expansion between insulation conductor and pressure casing, over the entire range of operating temperature.</p>
4. Cooling system	<p>One number external high pressure cooler for each motor rated for 100% duty shall be provided to remove the heat generated by the motor and bearings during operation. The temperature of high pressure cooling water leaving the motor cavity to the cooler shall not exceed 60°C. The cooler shall be adequately sized to reduce this temperature to 50°C.</p> <p>The design shall be such that during hot standby service of the pumping unit, sufficient cooling effect is provided by natural circulation of the coolant so as to prevent over heating of the motor.</p>

6.5.6 Superheaters & reheaters

- i) Superheaters and reheaters shall be designed, suitably sectionalized and positioned to comply with the following, for the specified load(s), coal(s) and for normal, upset, most adverse and other operating conditions:

a)	Rated steam temperature	As indicated at clause 6.2 above.
b)	Maximum average flue gas velocity in section/ tube banks with transverse tube pitching of 600 mm or less and with 25% excess air at economizer outlet	10 m/sec (maximum localized velocity across the cross-section not to exceed 12 m/sec) <i>For high GCV low ash (say 10% and below) coals: 12 m/sec (maximum localized velocity across the cross-section not to exceed 14 m/sec)</i>



c)	Maximum allowable tube skin temperature	40 ⁰ C below oxidation metal limit for the tube metal.
d)	Means of temperature control: 1. Superheaters 2. Reheaters*	Spray water attemperation, (utilising water tapped off from downstream side of HP heaters or intermediate banks of economizer or economizer outlet). Tapping of spray water upstream of top HP heater is not allowed. Tilting of burners/ gas biasing/ gas recirculation (gas to be tapped off after ID fans), spray water attemperation (utilising water tapped off from interstage of BFP).

***Note:** In case gas recirculation system is offered for reheat temperature control, minimum 2x100% gas recirculation fans with atleast 20% margin on flow and 44% margin on head over calculated maximum requirement of fan flow and head respectively shall be provided for each Steam Generator.

ii) Construction of superheaters & reheaters shall have following features:

a) Heating surfaces arrangements:

1. Completely drainable tubes/ banks/ sections for SH/ RH tube banks in case of tower type gas path arrangement. For the two pass boilers, the arrangement of SH/ RH banks shall have a drainable layout to the maximum possible extent.
2. Banks/ sections/ tubes should be made from seamless tubes.
3. In case of single fire vortex boiler, ensure even temperature distribution at gas and steam side by criss-crossing the steam paths between LHS and RHS.
4. Use of girdling loops shall not be permitted except in case it is standard practice of the manufacturer.
5. Elements shall be uniformly spaced to avoid gas bypassing.
6. Use of radiant wall superheater shall not be allowed.

Note: If design with radiant wall reheater is intended, the use of such radiant wall reheater shall be restricted to only on one of the furnace walls (i.e. either on the front wall or on one of the side walls). Further, the lowest portion of wall RH shall not be below the furnace nose tip level.



b) Minimum transverse tube pitching in the direction of gas flow path:

1. 600 mm for banks/ sections placed in areas where gas temperature exceeds the FEGT (MHVT) value.
2. For bank/sections placed in areas where gas temperature exceeds IDT of ash for the range of coals specified, the minimum transverse pitching shall be under:
 - For tower type boiler - 1000 mm
 - For two pass boiler - 762 mm

c) Maximum depth of tube banks/sections in the direction of gas flow shall be 2.5 meters or maximum soot blowing radius, whichever is lower.

d) *Supporting arrangement*

All horizontal heat transfer surfaces shall be supported by steam or water cooled hanger tubes designed for a minimum of 2 times the calculated load so as not to cause any dislocation/ damage to the tube banks/sections. The stress in the hanger tubes under such condition also shall not exceed the maximum permissible limits as per IBR. Erosion allowance of one (1) mm shall be provided over and above the calculated thickness of hanger tubes.

e) *Arrangement of headers*

Headers shall be located out side the gas path and shall be fully drainable. Wherever, locating the headers in the gas path becomes unavoidable these shall be suitably protected with erosion shields/ protectors. Further, the nipples and studs of the header shall also be provided with wear resistance stainless steel shields of minimum 2.5 mm or higher thickness. The arrangement of headers shall be such that it does not cause the high localised flue gas velocity on tubes down stream side of the header.

f) *Attemperators*

1. Location : At inlet or between the two SH/ RH stages.
2. Construction : Made from corrosion/ erosion resistant steel and fitted with removable liners.

g) *Minimum tube thickness*

1. *For leading tubes of the bank:* Erosion allowance of 1.0 mm (minimum) over and above the calculated thickness as per IBR shall be provided.



2. *For balance of the tubes in the bank:* Erosion allowance of 0.6 mm (min.) over and above the calculated thickness as per IBR shall be provided.
3. Minimum tube thickness at the bends in no case shall be less than the minimum tube thickness for the straight tubes calculated in the manner described at (1) and (2) above. For this purpose appropriate thinning allowance shall be considered while calculating the thickness of the bends.

h) *Tube/ header material*

1. The material chosen shall be appropriate for most adverse operating conditions specified. Alloys containing Molybdenum only, without any suitable stabilization with Vanadium and Chromium shall not be used. Total content of Molybdenum, Tungsten, Silicon, Vanadium, Titanium, Tantalum etc., individually or all together, if not otherwise specified, shall not exceed the limit specified in relevant material codes.
2. Use of different grades of tube materials in one SH/ RH bank shall be limited to three in flue gas path. One SH/ RH bank is defined as tubes/ elements connected between two headers.
3. Dissimilar metal welds (DMW) in gas path shall not be allowed for site welding.

iii) Superheater(s)/ reheater(s) design shall cater to following operational requirements throughout the control range of steam generator, with whole range of specified fuels and under all operating conditions like, HP heaters out of service, HP/ LP bypass operation, top mills in service etc.:

- | | |
|--------------------|--|
| a) SH outlet steam | Suitable to achieve minimum 565 ⁰ C at turbine inlet. Indicative value- minimum 568 ⁰ C. |
| b) RH outlet steam | Suitable to achieve minimum 593 ⁰ C at turbine inlet. Indicative value- minimum 596 ⁰ C. |

Note: The control system for SG shall be able to maintain SH/RH outlet temperatures within $\pm 5^{\circ}\text{C}$ of above values over complete control range of Steam Generators.

- c) Preferred mill combination Any combination of mills (as per purchaser's choice).



d) Maximum permissible spray attemperation flow (as percentage of main steam flow at superheater/ reheater outlet)

- | | |
|------------------------------|---|
| 1. Superheater attemperation | 8% of main steam flow at superheater outlet. |
| 2. Reheater attemperation | 3% of steam flow at reheater outlet (0% under normal operating conditions). |

Above permissible limits shall be applicable to all boiler loads with any combination of mills in service and shall be guaranteed. The SH/ RH attemperation system shall, however, be sized for 12% of the rated main steam flow requirement for superheater and 8% of the spray flow rated reheat flow for reheater, both at 100% BMCR load. The steam temperature downstream of desuperheater shall have at least 10⁰C superheat to ensure proper evaporation.

- | | |
|---|-----|
| e) Spray water carryover | Nil |
| f) Maximum steam side header pressure unbalance | 6% |
| g) Ash bridging between the tubes | Nil |

Note: The steam generator design shall ensure that no damage is caused to the reheaters with sudden closure of turbine interceptor valve.

iv) For continuous monitoring of tube metal temperatures of SH and RH elements, adequate number of thermocouples shall be provided as per standard and proven practice of the OEM. A suggested criterion for provision of thermocouples is indicated as below:

- For superheaters and reheaters elements placed before furnace exit plane (in the direction of gas flow), chromel-alumel thermocouples on at least two elements of every fifth assembly between the two headers shall be provided.
- In addition to the above, adequate number of chromel-alumel thermocouples for measurement of tube metal temperatures outside the gas path shall also be provided. Total number of thermocouples including those at (a) above shall, however, not be less than 2 (two) thermocouples per RH/SH assembly between the two headers.

v) For maintenance/inspection of SH/RH:

- 1.5 m clear cavity height shall be provided between two sections/banks of horizontal heat transfer surfaces for personnel access. For vertical surfaces, minimum clearance between the two banks shall be 600 mm.



- b) Access openings alongwith air/ gas tight hinged doors shall be provided for approach to above maintenance spaces without any hindrance from hanger tubes.
 1. All access door shall be of 450mm x 450mm size (minimum).
 2. Access doors 800 mm above the nominal floor level shall have access platform.
 3. Hanger tubes of horizontal banks shall have access opening for crossing over.
 - c) Stainless steel erosion shields shall be provided for all bends of outermost tube/ coil of all SH/ RH sections and hanger tubes in areas where flue gas temperature is below FEGT. For the pendant tube sections, the erosion shield shall be provided on the leading tubes and wherever else considered necessary as per the proven design.
 - d) Suitable arrangement for internal inspection of attemperators/ headers shall be provided.
- vi) Headers and pipes, if made using X-20 Cr MO V 121 to DIN 17175 material, shall have provisions to ensure that no site welding of this material with similar or dissimilar material is needed.

6.5.7 Economisers

- i) Economizer design shall conform to the following criteria/requirements under all condition of operation and for the complete range of specified fuels.

a)	Economizer type	Non-steaming type with parallel cross flow or counter flow arrangement.
b)	Approach temperature within control range	17°C (minimum).
c)	Maximum average flue gas velocity through the economizer tube banks, with 25% excess air at economizer outlet.	10 m/sec (maximum localized velocity across the cross-section not to exceed 12 m/sec). <i>For high GCV low ash (say 10% and below) coals:</i> 12 m/sec (maximum localized velocity across the cross-section not to exceed 14 m/sec).
d)	Economizer tube thickness	i) Erosion allowance of 1mm (minimum) shall be provided in addition to thickness calculated as per IBR formulae.



		ii) Minimum tube thickness at the bends in no case shall be less than the minimum tube thickness for the straight tubes calculated above including erosion allowance. For this purpose appropriate thinning allowance shall be considered while calculating the thickness of the bends.
e)	Maximum allowable tube metal skin temperature	Oxidation limit for the tube metal.
f)	Maximum depth of tube banks/ sections in the direction of gas flow	2.5 m or maximum soot blowing radius whichever is lower.
g)	Thermal shock aspect	The economiser shall be suitably designed to take a thermal shock of sudden change of feed water temperature from rated value to approximately 140 ⁰ C during HP/LP bypass operation.

ii) Construction of economizer shall have following features:

- a) Economiser shall be bare tube and inline type, arranged for counter flow of feed water and flue gases in case of two pass boiler and parallel cross flow of feed water and flue gases in case of tower type boiler.
- b) Economiser shall be fabricated from seamless tubes complete with spacers and supports etc. to facilitate erection at site.
- c) Minimum 3.0 mm thick stainless steel erosion shields shall be provided for leading tubes of each tube bank of economizer. In addition minimum 5.0 mm thick sturdy cassettes baffles shall be provided for all front side and rear side bends of the economizer banks. The cassette baffles shall cover complete bends and additional 300 mm straight tube length.
- d) Economiser shall be supported by steam/ water cooled hanger tubes/headers forming part of steam circuit with hanger tubes designed for a minimum of 2 times the calculated load so as not to cause any dislocation/damage to the tube banks/ sections.
- e) Economiser shall be provided with minimum 50 mm clear side spacing (gas lane), with proper barriers installed, to avoid gas laning.
- f) Economiser shall be without any valve in the pipeline from the economizer outlet to evaporator section of steam generator.



- g) If the Steam Generator has the flue gas down-flow section with horizontal tube banks, the top most row shall be shielded to reduce erosion.
 - h) Headers shall be located external to gas path and shall be completely drainable. If locating headers in gas path becomes unavoidable, than suitable erosion shields/ protectors must be provided.
 - i) Economiser shall be provided with ash hoppers along with high ash level switches/ alarms, if economizer is placed in the second pass of Steam Generator.
 - j) Wet ash handling system is intended for evacuation of ash collected in the economizer & economizer bypass hoppers (if applicable). Sufficient head room below the economizer/ economizer bypass hoppers shall be ensured to accommodate the ash handling equipment. A minimum headroom of 2.5 m shall be kept between hopper flange and platform to accommodate the ash handling equipments. To enable the ash/slurry pipes from economizer/ economizer bypass hoppers to be routed with minimum bends, it may be required to pass vertically through the air/ flue gas ducts. In such a case it is envisaged that a pipe sleeve shall be provided within the ducts through which the ash/ slurry pipes may be routed.
- iii) Economizers shall also meet following requirements:
- a) Minimum 1.5 m clear cavity height between two sections/banks of the economizer for maintenance access.
 - b) Access /opening for each tube banks alongwith air/ gas tight hinged doors.
 - c) Arrangement (structural steel/runway beams, motorized hoists, walkways platform alongwith runway beams etc.) for removing, handling and placement of tubes banks/section at ground level for repair/ replacement. The size of platforms shall be adequate to store 5-6 economizer assemblies as well as adequate space for handling them.
 - d) Arrangement for off load water washing for economizer with necessary drainage connected to nearest drain, if two pass boiler is offered.
 - e) The header shall be provided with drains and suitable opening with forged weld on caps for internal inspection and chemical cleaning. Inspection openings with forged weld on caps shall be provided for headers.



iv) *Space Provision*

Space provision shall be kept on gas inlet side for installation of atleast 20% additional economizer surfaces, if required, in future. Structure/hanger design shall be suitable for loads due to these additional surfaces (filled with water) also.

6.5.8 **Air pre-heaters**

i) Design requirements of the air pre-heaters shall be as below:

a)	Type	Regenerative type tri-sector air pre heaters with facility of steam coil heating on secondary air side to guard against low cold end temperature. or Regenerative type bi-sector air pre heaters for primary air and secondary air with facility of steam coil heating both on primary air side and secondary air side to guard against low cold end temperature.
b)	No. of air preheaters per steam generator	Two tri-sector type APH or two bi-sector type APH each for primary air and secondary air.
c)	Design ambient air	27°C and 60% RH.
d)	Boiler load to be	1. 60% BMCR with design/ best/ worst coal and maximum moisture whichever gives maximum flow with one set of APH in service. 2. 100% BMCR with design/ best/ worst coal and maximum moisture whichever gives maximum flow with both sets of APH in service.
e)	Air temperature rise across air preheater	Adequate to achieve the required coal/air mixture temperature at burner inlet at all loads and for complete range of specified coals.
f)	Minimum average cold end metal temperature at 100% BMCR (with SCAPHs out of service)	76 ⁰ C
g)	Minimum AH flue gas exit temperature (corrected) at 100% TMCR with range of specified coal	125 ⁰ C



h)	Minimum flue gas exit temperature (for complete range of specified fuels)	5 ⁰ C above acid dew point of flue gas.
i)	Air leakage (at 100% TMCR load for complete range of coals)	10% of the flue gas weight entering air-heater.

ii) For meeting the requirement of rated coal/ air mixture temperatures at burner inlet at part load operations of steam generator with coals of excessive moisture and under conditions of low ambient temperatures, economizer bypass duct may be provided along with necessary dampers, expansion joints, structures etc. Even in case economizer bypass is provided, the sizing of air preheaters shall ensure that the rated mill outlet temperatures are achieved, for complete range of specified coals, with economizer bypass fully closed.

iii) APH inlet/ outlet flue gas/ air ducts shall have aerodynamic design for even distribution of air/ flue gas at all loads.

iv) The air pre heaters shall be of rotary regenerative, Lungstorm or approved equivalent type with axis of rotation as vertical. The construction of air pre heaters shall conform to the following:

a) Heating Elements

1. Cold end : Corten steel, minimum 1.2 mm thick
2. Hot/intermediate end : Carbon steel, minimum 0.8 mm thick

b) Bearings (forced lubricated and oil cooled)

1. Cold end : Spherical roller thrust bearing
2. Hot end : Radial guide bearing

Note: Only metallic hoses shall be used for bearing cooling/ lubrication. Rubber hoses shall not be acceptable.

c) Air heater seals

1. Externally (manually/ automatically) adjustable and easily replaceable type.

2. The maximum air-in-leakage to flue gas after 3000 hours continuous operation of the Steam Generator with coal shall be guaranteed and demonstrated. It shall also be demonstrated that the drift in air heater leakage (percentage change in air-in-leakage) does not exceed 1%, one year after demonstration of above guaranteed air-in-leakage.

3. Seals shall have life of not less than 2 years (with leakages not exceeding guaranteed limits).



- d) Air heater drive
1. One (1) no. peripheral AC drive or central AC drive as per OEM's proven practice with gear box and automatic clutching/ declutching facility.
 2. One (1) no. auxiliary air motor drive with automatic clutching, declutching facility for rotation during non availability of A.C. drive system.
 3. An air receiver tank of storage capacity adequate to operate air pre-heater using air motors for 10 minutes (minimum) with no air make-up during this period.
- v) Two nos. inlet oil carryover detection probes shall be provided for each APH.

6.5.9 Steam coil air pre-heaters (SCAPHs)

- i) SCAPHs shall be designed/ sized to increase the air heaters inlet air temperature based on following criteria:

a)	Design ambient air temperature	6 ⁰ C
b)	Number of SCAPHs	One (1) for each FD fan in case of tri-sector type APH. or One (1) for each FD fan and one (1) for each PA fan in case of bi-sector type APH.
c)	Air temperature at SCAPH outlet	1. At 100% BMCR: 27 ⁰ C (minimum). 2. At 30% BMCR during oil firing: 100 ⁰ C (minimum).
d)	Air temperature at the inlet of each air pre-heater	To keep average metal temperature (cold end) at least 76 ⁰ C with coal firing and 100 ⁰ C with oil firing.

- ii) SCAPH and connected air ducts shall be designed to handle flows corresponding to 60% BMCR loads with one of the two streams working without any undue noise/ vibration.

6.5.10 Soot blowing system

- i) *Type of Soot Blowers*

a)	For furnace chamber	Short rotary, Single nozzle retractable type.
b)	For horizontal heat exchanger section	1. Long rotary, multiple nozzle, retractable type for high temperature zones.



		2. Short rotary, multiple nozzle, retractable type for low temperature zones.
c)	Air-preheaters	Power driven swinging arms soot blower, or retractable multi-nozzle soot blowers.

- ii) Soot blowing system shall be:
 - a) capable of effectively removing deposited ash from steam generator heat transfer surfaces with on- load cleaning devices. The soot blower design shall be of self draining type.
 - b) fully automatic & sequentially controlled through SG C&I control system. Alternately, a SMART Soot Blowing system based on heat flux sensors and flue gas exit temperature may be implemented with a fall back to sequential control, if required.
- iii) The design of air-heater soot blowing system including piping, valves & fittings shall allow use of high temperature steam from high temperature auxiliary steam header during start-up. A check valve and/or motor operated valve shall be provided on this high temperature line to prevent normal soot blowing steam from entering auxiliary steam header. In case soot blowing steam is required at parameters other than those available from auxiliary steam system, for the purpose of efficient soot blowing during start-up and other loads, a permanent arrangement shall be provided for the same.
- iv) Soot blower elements shall be made of extra heavy seamless tubing from solid bars with heat, corrosion & erosion protection in permanent contact with hot gases. The Blowing element shall be of high temperature alloy steel.
- v) Retractable soot blowers (RSB) shall be retractable even during emergencies such as drop in steam supply pressure, low steam flow, etc. Long retractable soot blowers (LRSBs) shall be half of steam generator width on each side. Double helix cleaning pattern shall be used. Dual electric drives, one for rotary and other for linear motion shall be provided for each soot blower. Alternatively, soot blower design having both linear as well as rotary motion achieved through single drive motor shall also be acceptable.
- vi) All soot blowers shall be suitable for local and remote automatic sequential operation.

6.5.11 Walkways, platforms and stairs

- i) Access platforms, walkways, handrails, stairs, ladders and gratings etc. for proper approach during maintenance shall be provided for steam generator, all auxiliaries, equipments and accessories. Walkways,



platforms, stairs & ladders shall be provided in accordance with following requirements:

Description	Minimum clear width*
a) Main access walkways	1200 mm
b) Staircase	1000 mm
c) Ladders **	450 mm
d) Platforms	1200 mm

* The clear width indicated shall be without any interruption from the intervening pipes, columns, actuators, instrument enclosures, racks etc.

** Ladders shall be provided only in such cases where it is not possible to provide stairs and except at places where ladders have been specifically specified.

- ii) Platforms shall be provided at all burner levels, all around the furnace, such that there is adequate space for operation, service and maintenance of all burners and associated auxiliaries. The burner platforms shall be minimum 3000 mm wide and shall extend from furnace walls. Platforms shall allow complete burner withdrawal within boiler enclosure.

Platforms at each burner elevation shall be continuous and run at the same level without any interruptions from intervening steps, obstructions etc. Burner platforms within 200 mm of an igniter shall be welded steel chequered plate with welded-in-place drains to prevent oil spillage from spreading.

Burner platforms shall have direct access to elevator and access stairs to each burner level shall also be provided.

- iii) Platforms of minimum clear width of 1200 mm shall be provided on at least three sides of the control station/ equipment. The platforms shall be all along the length of soot blower control station, fuel oil control station, SH & RH spray control stations, SCAPH control station, steam/ water sample coolers, APH lube oil station etc. Access through elevator, staircase and main access walkways for reaching the platforms shall be provided.
- iv) Soot blowers shall have platforms on both sides along the entire length of retractable soot blowers with adequate space and service area for removal and handling of rotary blower elements in one piece.

All LRSB's shall have minimum 1200 mm wide platforms on both sides along the entire length of soot blowers. Platform width should provide adequate space and service area for removal and handling of blower elements in one piece. Access through elevator/ staircase and main access walkways for reaching the LRSB platforms shall be provided.



- v) All manholes, all access doors, all observation ports, all instruments including flame scanners, flame cameras & ash level indicators, junction boxes for control and instrumentation, all instrument test/ sampling points including that for PADO and all dirty pitot tube & coal sampling points shall be accessible from main access walkway/ platforms. In case the lowest point of the manhole/ access door/ exceeds 800 mm and of observation ports/ dirty pitot tube & coal sampling points/ instruments exceeds 1200 mm from the nearest walkway/ platforms level then suitable intermediate platform to each of the above access doors, observation port, sampling points, instruments etc. along with suitable approach from nearest platform level shall be provided. Minimum height of the observation port shall be 500 mm from the platform/intermediate platform.
- vi) Suitable all round platform of 1000 mm clear width shall be provided for manual operation of all valves, for all dampers, for ash hoppers, APH drives, for all lubricated equipment bearings and equipments requiring access during operation for normal day to day inspection & maintenance. Suitable access to these platforms shall also be provided.
- vii) All around platforms of clear width of 1000 mm and adequate to permit at least two persons to simultaneously work (1.5 sq.m. minimum) shall also be provided for all damper actuators, valve actuators, safety valves, instrument source connection point, Y pieces, expansion joints and other areas requiring access only monthly or annually. Suitable access to above platforms with walkways, stairs/ ladders etc. shall be provided.
- viii) Platform should be provided for removal and handling of startup drain re-circulation pump, motor, cooler. Direct access through elevators without use of stairs for reaching the platforms shall be provided.
- ix) Annular platforms of 1200 mm clear width accessible by stairs/ladders shall be provided for mill discharge valves & bunker outlet gates.
- x) Continuous platforms of minimum clear width of 1500 mm shall be provided all around furnace seal trough level. Access to these platform levels shall be by staircase.
- xi) *Storage Platforms*

In addition to maintenance platforms, walkways etc. specified above, storage platforms shall be provided for storing of scaffoldings, APH baskets and platforms for removal and handling of economizer and reheater and other maintenance items required during overhaul of steam generator(s) in accordance with the following:

- a) **Scaffoldings:** Adequate platforms around scaffolding entry point for storing of maintenance cradle/ quick erected scaffoldings prior to commencement of maintenance/ overhaul activities. Weight of maintenance cradle/quick erected scaffoldings shall be accounted in the structure and platform design.



- b) **APH baskets:** Adequate platforms with proper approach near APH(s) for storage of at least 40 nos. baskets for each APH. Weight of stored APH baskets shall be accounted in the structure and platform design.
- c) **Economizer, superheater and rerheater:** Platforms for handling of at least 3 rows of largest size coils and storage of at least 8 rows of largest size coils of economizer, superheater and reheater (all horizontal heating surfaces in second pass) coils shall be provided. Adequate platforms, walkways, access/stairs shall also be provided for removal of second pass water walls/casing, buckstays and installation of monorails, hoist etc. Weight of above coils and equipments required for handling shall be accounted in the structure and platform design.
- xii) It shall be ensured that the layout and routing of pulverized coal (PC) pipes is such that horizontal sections of PC pipes & bends are accessible from the nearest platform or walkway level, to the extent possible, to facilitate their replacement during maintenance.
- xiii) Access to all penthouse cooling doors shall be provided through maintenance walkways of minimum 1000mm width.
- xiv) Walkways/ platforms/ staircase etc. shall comply with following requirements also:
 - a) Platforms at same elevation on each side of steam generator shall have a walkway connecting the two sides.
 - b) Platforms requiring access from the elevator shall extend to the elevator entrance by main access walkways and be attached to the elevator steel as required.
 - c) Minimum headroom (free height) under all floors, walkways and stairs shall be 2.2m. The interconnection between two platforms/ floors at different elevations shall be through proper staircase. Ladders shall be considered only in exceptional case where provision of staircase is not possible.
 - d) Hand railings shall be provided for all walkways, platforms, openings, staircases etc.
 - e) If material is stacked or stored on a platform or walkway, or near a floor opening, kick plate/ toe guard must be increased in height or solid or mesh panels of appropriate height must be installed to prevent the material from falling.



- f) All areas subject to lube oil or chemical spills will be provided with curbs and drains.
- xv) Two main stairways shall be provided one on each side of the steam generator. One stairway shall extend continuously from grade to the highest operating level and the other shall extend continuously from grade to the boiler roof. Steel framing for penthouses for each stairway shall be provided. The portion of main stairway within the enclosed portion of the building, if any, shall be designed for one hour smoke/ fire proof requirements.

6.5.12 Elevators

Elevators shall be designed based on following criteria:

i)	Type of service	One (1) no. passenger-elevator in TG hall and one (1) no passenger cum goods elevator in boiler area per unit.
ii)	Design/ construction/ installation codes	a) Latest edition of IS: 14655 (all parts) and also meeting any additional requirements of IS: 4666, IS: 1860 and IS: 3534.
		b) Any other equivalent code
iii)	Load carrying capacity	1088 kg (equivalent to 16 person) for passenger elevator & 3000 kg for passenger cum goods elevator.
iv)	Rated speed	0.55 m/sec for 3000 kg capacity elevator and 1.0 m/sec for 1088 kg capacity elevator.
v)	Total travel	As per steam generator supplier's recommendations.
vi)	Number of floors to be served	Ten (minimum).
vii)	Entrances	Twelve (12) (minimum) (all on same side).
viii)	Entrance and platform size	As per design/ installation codes at (ii) above.
ix)	Elevator landings (min.)	a) Ground floor.
		b) Mezzanine floor of TG hall.
		c) Main operating floor of TG hall.
		d) All burner platforms.
		e) Alternate soot blower levels.
		f) Coal gallery.
		g) Steam separator.
		h) At all regularly operating platforms.
		i) Laboratory floor.



CHAPTER 7

DRAFT FANS, DUCT WORK AND DAMPERS

7.1 Forced Draft and Induced Draft Fans

The forced draft (FD) and induced draft (ID) fans shall be capable of maintaining balance draft conditions in the furnace upto 60% BMCR load with any one or both FD fans and any one or both ID fans in operation and above 60% BMCR load with both FD fans and both ID fans while firing the specified range of coals.

7.1.1 Fan sizing criteria

FD & ID fans shall be sized such that they satisfy the criteria stipulated below:

Description		FD Fans	ID Fans
i)	Type of fans	Constant speed, axial type	Constant speed, axial type
ii)	No. of fans per unit	Two	Two
iii)	Fan sizing criteria with all the following conditions occurring together	Each fan to be sized for 60% BMCR load (one stream in operation) calculated taking into account following factors occurring together:	
a)	Type of coal firing	Design / best / worst coal whichever gives maximum FD fan air requirement	Design / best / worst coal whichever gives maximum flue gas flow
b)	Power supply frequency	47.5 Hz	47.5 Hz
c)	Excess air	20% over the stoichiometric air	20% over the stoichiometric air
d)	Fan inlet air/ flue gas temperature	50 ⁰ C temperature with 65% relative humidity	Gas temperature corresponding to 50 ⁰ C ambient temperature and 65% relative humidity
e)	Air-heater air-in-leakage	Minimum 10% of flue gas flow entering APH, or actual guaranteed leakage whichever is higher	Based on min. 15% of gas flow entering primary side and min. 10% of gas flow entering secondary side APH or actual guaranteed leakage whichever is higher
f)	Pressure drop through ESP	Not applicable	25 mmwc
g)	Air in leakage	Not applicable	1% of ESP inlet gas flow & 2% through ducts
h)	Pressure required at chimney inlet	Not applicable	+ 10 mmwc



7.1.2 Fan sizing criteria- Additional

The fans shall also fulfill following sizing criteria in addition to those mentioned at 7.1.1 above:

Description	FD Fans	ID Fans	
	Each fan to be sized for 50% BMCR flow calculated taking into following conditions occurring together:		
i)	Margin over flow	20%	20%
ii)	Margin over pressure with two fans meeting 100% BMCR requirement	44%	44%
iii)	Type of coal firing	Design/ worst / best coal whichever gives maximum FD fan flow	Design/ worst/ best coal whichever gives maximum flue gas flow
iv)	Excess air at economizer outlet	20% over stoichiometric air requirement	20% over stoichiometric air requirement
v)	Fan inlet air/ flue gas temperature	50 ⁰ C temperature and 65% RH	150 ⁰ C or actual gas temperature corresponding to 50 ⁰ C ambient temperature and 65% RH, whichever is higher
vi)	Air-heater air-in-leakage	Min. 10% of flue gas flow entering APH, or actual guaranteed whichever is higher	Based on min. 15% of gas flow entering primary side and min. 10% of gas flow entering secondary side APH or actual guaranteed leakage whichever is higher
vii)	Power supply frequency	50 Hz	50 Hz
viii)	Pressure drop through ESP	Not applicable	25 mmwc
ix)	Air in leakage	Not applicable	1% of ESP inlet gas flow & 2% through ducts
x)	Pressure at chimney inlet	Not applicable	+10 mmwc

Note to 7.1.1 & 7.1.2:

- i) ID/ FD fan shall have a minimum stall margin of 10% over the design duty points.



- ii) Both FD fans and both ID fans shall operate with highest possible efficiency which shall be nearly equal at the 100% TMCR and test block points depending upon margin on flow and pressure.
- iii) Fan components alongwith servo/ blade pitch control mechanism shall be designed to withstand and continuously operate with the maximum air or flue gas temperature that these fans will be required to handle. ID fan component shall also be designed to withstand the excursions in flue gas temperature up to 300⁰C, which may persist for about 30 minute duration. Such temperature excursion will not inhibit the safe and smooth operation of fans or cause any damage or increased maintenance.

7.1.3 Fans operational requirements

Description		FD Fans	ID Fans
i)	Mode of operation	a) two fans in parallel.	two fans in parallel.
		b) one fan (one stream in operation).	one fan (one stream in operation).
ii)	Fan control system	a) capable of operating in automatic mode for all regimes of operation in a steady and stable manner.	capable of operating in automatic mode for all regimes of operation in a steady and stable manner.
		b) The final control element shall not have any black-lash, plays etc., and shall operate in the range of 20% to 80% depending upon generating loads upto Boiler MCR.	The final control element shall not have any black-lash, plays etc., and shall operate in the range of 20% to 80% depending upon generating loads upto Boiler MCR.
iii)	Parallel operation	The fans shall be suitable for parallel operation and sharing the load capacity over the entire range of operation without hunting. Pulsation shall be avoided by suitable design of fans.	

7.1.4 Fan construction features

- i) The construction of FD & ID fans shall comply with following requirements:

Description		FD Fans	ID Fans
a)	Type of fan blades	Streamlined, aerofoil shaped section	streamlined, aerofoil shaped section
b)	Blade material	high strength aluminum alloy, BHN-75 (min.)	Nodular Cast Iron or high wear resistant steel with or without hard coating as per the fan manufacturer



c)	Fan rotational speed	1500 rpm (max.)	750 rpm (max.)
d)	Air/ flue gas flow control	blade pitch control	blade pitch control
e)	Fan critical speed	not less than 125% of fan maximum operating speed	not less than 125% of fan maximum operating speed
f)	Fan component design*	to withstand torsional stresses three (3) times the normal/ full load motor torque at all speeds	to withstand torsional stresses three (3) times the normal/ full load motor torque at all speeds
g)	Fan casing material & thickness	Carbon steel, 6.00 mm (min.)	Abrasion and wear resistant, high BHN steel having minimum 8.0 mm thickness or 8mm mild steel with liner of thickness 10mm (min.)
h)	Fan Housing design pressure	Shut off head of fan	Shut off head of fan

* The ID fan components such as blades, hubs, casing etc. shall be chosen to encounter the high dust burden of the order of 250 mg/Nm³. The minimum wear life of ID fan components shall not be less than 25000 hours of operation from the date of commissioning.

ii) Silencers shall be provided at the suction of FD fans to limit the noise level as specified. FD fan suction shall be provided with rigid bird and trash screen assembly and shall have suitable arrangement to avoid rainwater from directly entering the fan.

iii) *Fan Bearings*

- a) Bearing shall be provided with oil bath to prevent damage in case of complete loss of plant auxiliary power when the fans must coast down without power.
- b) Oil reservoir in bearings housing shall be sized for maintaining lubrication for extended periods in case of oil circulation system is out of service.
- c) Duplex Pt-RTDs (100 ohm at 0°C) and temperature indicators shall be provided for each bearing as per standard practice of the OEM for local as well as remote monitoring of bearing metal temperature.
- d) For mounting of vibration pads/ pickups, flat surfaces shall be provided both in X and Y directions, on the bearing housing.



iv) *Fan Balancing*

The fans shall be statically and dynamically balanced before shipment and balancing of each fan shall be checked and adjusted at site, if necessary.

7.1.5 Flow measuring devices

- i) The draft plant shall include flow measuring devices in the air system for total air flow measurements and control with adequate number of tapping points.
- ii) Three independent pairs of tapping points with the necessary isolating valves shall be provided for control, measurement and test.
- iii) Two nos. duplex temperature element with thermowells for temperature compensation shall be provided.
- iv) Fan inlet flow measurement shall be provided using fan inlet elbow. However, if such an arrangement is not possible, flow element (venturi/aerofoil system) shall be provided with three pair of tapping points at suction of each FD Fan.

7.2 Duct Work

7.2.1 Duct work sizing criteria

- i) Allowable velocities in the duct work shall be as below.
 - a) Maximum velocity for cold air and hot air shall be 16 m/sec and 20m/sec respectively.
 - b) Maximum gas velocity shall be 13 m/sec (15 m/sec for units based on high GCV low ash coals) except in flue gas duct from ID fan outlet to chimney inlet, where the maximum velocity limit can be 16 m/sec.
- ii) The velocities in the ducts shall not exceed the above limits under the following conditions, all occurring together:
 - a) Design/ best/ worst coal firing at 100% BMCR load whichever gives maximum flow.
 - b) 25% excess air over and above the stoichiometric air at economizer inlet.
 - c) Air heater air in leakage 10% for secondary air and 15% for primary air or actual guaranteed whichever is higher.
 - d) Design ambient temperature of 27⁰C and 60 % RH.



The above velocities shall not be exceeded even in case of operation with one stream of ID, FD, PA fans and air heater operation at 60% of BMCR load.

7.2.2 Loads for duct and structure design

The duct design shall take into account following loads all occurring together:

- i) Wind loads.
- ii) Dead weight including weight of insulation, lining, wash water and the vertical live load.
- iii) Horizontal ducts to be designed for minimum 245 kg/m² additional fly ash loading on the surface or for one fourth of duct full of ash or for maximum possible accumulation of ash in the ductwork, under all normal, upset or abnormal operating conditions, whichever is higher. Flue gas ducts downstream of ESP shall be designed for additional fly ash loading on the surface as above or for one tenth of duct full of ash or for maximum possible accumulation of ash in the ductwork, under all normal, upset or abnormal operating conditions, whichever is higher. The ash accumulation considered for economizer bypass duct (if provided) upto Guillotine gate shall be 100% filled with ash. The ash density for the purpose of loading shall be taken as 1350 kg/m³.
- iv) Expansion joint reaction.
- v) The following minimum load factors shall be applied to the design loads for duct work (excluding support structure):

Temperature (°C)	27	37	93	149	205	260	316	321
Loading factor	1.00	1.02	1.12	1.19	1.25	1.29	1.34	1.42

- vi) The ductwork and its structure shall take into account loads due to future addition of FGD interconnection ducts and dampers in the duct between ID fan outlet and chimney inlet transition piece.

7.2.3 Duct design pressure

All flue gas ducts, air ducts and the wind boxes shall also be designed for ± 660 mmwc pressure or maximum conceivable pressure of the relevant fans, whichever is higher, at 67% of yield strength of material.

7.2.4 Type of duct construction

The ducts shall be of rectangular cross-section and shall be of all welded construction. Following requirements shall be complied with:



- i) Minimum 8 mm thick steel plates for gas ducts from APH outlet to ESP inlet and minimum 6 mm thick steel plates for gas ducts from ESP outlet to the chimney inlet.
- ii) Minimum 5 mm thick steel plates for air ducts.
- iii) A corrosion allowance of 1.5 mm shall be considered for stress calculation for the flue gas ducting.
- iv) Duct stiffening shall be by means of rolled sections.
- v) The thickness of the duct plate shall be suitably increased, if required, in the transition zone at steam generator outlet where the flue gases change direction, to increase the wear life of the duct plates.
- vi) Interconnection ducts shall be provided in air and gas system for flexibility of plant and equipment operation as necessary.

7.2.5 Material of construction

i)	Duct plates, turning vanes, perforated plates	ASTM A 36 or equivalent (suitable alloy steel for gas temperature above 400 ⁰ C)
ii)	Structural shapes	ASTM A 36 or equivalent
iii)	Pipe struts, trusses, bracing	ASTM A 53 or equivalent seamless steel pipe
iv)	Erection tools for ducts	ASTM A 307 or equivalent
v)	Bolts for connection to structural steel	ASTM A 325, AISIA 325 (friction type) or equivalent
vi)	Stainless Steel	ASTM A 316 L or equivalent
vii)	Access & inspection doors	Reinforced steel plates

7.2.6 Insulation & lagging

- i) Thermal insulation shall be applied to all air/ gas ducts to comply with the requirements as specified elsewhere in this document.
- ii) Acoustic insulation shall be used on air and gas ducts to restrict the noise level to specified values.

7.2.7 Expansion joints

- i) Metallic type expansion joints suitable for the service conditions shall be provided. The expansion joint design shall conform to the requirements of the EJMA Standards.
- ii) The expansion joints shall be of heavy duty construction. The expansion joint material shall be compatible with the flowing medium, the external environment and the operating temperature. Suitable corrosion and erosion allowances shall also be taken.



7.3 Dampers

7.3.1 Power operated gas tight isolation dampers along with their drives shall be provided at all locations required for carrying out internal repair and maintenance of pulverizers, electrostatic precipitators and induced draft fans when the steam generator is on load. As a minimum following locations shall be provided with power operated gas tight dampers/ gates:

i)	Guillotine gate type dampers	a)	In hot air duct at inlet to each mill.
		b)	On each twin inlet and twin outlet of each ESP stream.
		c)	Before and after each ID fan.
		d)	At inlet to each of the regenerative air pre-heaters on flue gas side.
		e)	At discharge of each of PA fan.
		f)	At each economizer bypass duct (2x100%) (if provided).
		g)	Interconnecting duct dampers as necessary.
ii)	Double multilouver/ bi-plane type dampers	a)	Before and after each of the regenerative air pre-heater & SCAPH on air side.
		b)	At discharge of each of FD fan.

7.3.2 Heavy duty multilouver dampers shall be provided at locations not requiring tight shut off duty.

7.3.3 Pneumatically or motor operated control dampers shall be provided at the following locations and a minimum:

- i) Hot and cold air inlet to each mill.
- ii) At each air preheater outlet on flue gas path (if applicable).

7.3.4 All dampers/ gates at ID fan discharge, primary and secondary APH outlets on air side, primary and secondary APH inlets on flue gas side and in hot air ducts to mill inlet shall be provided with 2x100% pressurization fans to achieve 100% sealing efficiency. Alternatively, the above dampers can be provided with sealing air from cold air bus duct suitably meeting the requirement of 100% sealing.

7.3.5 The multilouver dampers shall be capable of effectively stopping the flow when in closed position and while in full open position shall cause minimum pressure drop. The isolating damper design shall provide positive shutoff when closed.

7.3.6 All regulating dampers/vanes/blade pitch controls coming under auto regulation shall be able to provide the desired relationship between percentage opening and the flow.



- 7.3.7 The auto regulating dampers shall be capable of being operated between 20% to 80% opening as per the optimal requirements of control systems to achieve stable, steady and smooth automatic control of the plant and processes under all operating conditions.
- 7.3.8 There shall not be any backlash, play, etc. with linkage mechanism, actuator and final control element.
- 7.3.9 Outlet dampers of seal air fans, scanner air fans and emergency dampers of scanner air shall be pneumatically operated, suitable for remote manual operation.
- 7.3.10 All pneumatically operated interlocked dampers actuators shall be provided with solenoid valves. For open and close feed back of hot air gates, proximity (i.e. non-contact) or mechanical type limit switches (2NO+2NC) shall be provided. These shall be suitable for working hot & dust environment.
- 7.3.11 **Guillotine dampers**
- i) All guillotine dampers shall be located in horizontal duct to avoid fly ash build up when in closed position and shall be of top entry type.
 - ii) The Guillotine gate type dampers shall have a guaranteed gas tightness efficiency (on flow) of not less than 99.8% along the duct as well as from the duct to atmosphere or from atmosphere to the duct, depending on the pressure in both the damper open and damper closed condition without the use of seal air fans of the damper.
- 7.3.12 **Multilouver/ bi- plane dampers**
- i) The damper shall be of heavy duty construction.
 - ii) For preventing hot air or gases from escaping around damper shaft, double gland type stuffing boxes with graphite impregnated non asbestos packing material shall be provided on all damper blade shafts.
 - iii) The double multilouver/ bi-plane type dampers shall have sealing efficiency of 99.5% on flow without seal air, however with seal air it shall be 100%.



CHAPTER 8

COAL PREPARATION AND FIRING SYSTEM

8.1 General

- 8.1.1 Coal preparation and firing system shall commence with the shut-off valve at raw coal bunker outlet and shall include raw coal feeders, coal pulverizers, primary air & seal air fans, pulverized fuel pipes, coal burners, coal valves and associated auxiliaries.
- 8.1.2 The coal preparation and firing system design shall ensure complete safety of the plant, equipment and the personnel and shall be in compliance with the latest NFPA (USA) requirements and other requirements specified.

8.2 Bunker Shut Off Gates, RC Feeder Inlet & Outlet Gates

- 8.2.1 Bunker shut off gates & RC feeder inlet gates shall be suitable for 914.4 mm (36 inch) round bunker opening.
- 8.2.2 Bunker shut off gates shall be motor operated & RC feeder outlet gates shall be motor/ pneumatic operated and RC feeder inlet gates shall be manually operated with double rack and pinion drive arrangement and shall be designed for non-jamming. Gate design shall ensure dust tight enclosure. The gates valves shall be self cleaning type.
- 8.2.3 The bunker shut off gates and feeder inlet & outlet gates shall be totally enclosed construction to prevent leakage. Gate and shaft bearings shall be suitable for pressure lubrication. Stainless steel material shall be used for all components coming in contact with coal and roller bearings.
- 8.2.4 Bunker shut off and RC feeder inlet gates shall be designed to operate with "bunker full of coal" condition without its motor getting overloaded. Further, normal motorized as well as inching operation of these shut off gates should be possible from the feeder floor.
- 8.2.5 Bunker shut off gate shall ensure 100% closure of bunker outlet even under "bunker full of coal" condition without its motor getting overloaded.
- 8.2.6 Local push buttons for open/ close command and chain wheel & chain for manual operation of each gate/ valve from floor level shall be provided.
- 8.2.7 Adequate provisions shall be kept for sampling of coal.

8.3 Coal Chutes

- 8.3.1 The requirements specified herein apply to the following coal chutes:



- i) Chutes between outlet of raw coal bunker shut off valves and inlet to the coal feeders.
- ii) Chutes between outlet of coal feeder and inlet to the pulverizers.

8.3.2 The internal diameter of coal chutes selected shall not be less than following:

<u>Coal Chute</u>	<u>Minimum I.D.</u>
i) Between bunker outlet gate & feeder inlet	914.4 mm
ii) Between feeder outlet & pulveriser inlet	600 mm

8.3.3 Chutes shall be made of minimum 12 mm thick SS-410 material and shall be of full welded construction.

8.3.4 Provision shall be made for the insertion of poke rods in two directions at right angles to each other on the chute at outlet of the bunker and at inlet to the feeders.

8.3.5 The chute between feeder outlet and pulverizer inlet shall have a stainless steel lined hopper with suitable reinforcement.

8.3.6 Permanent chutes shall be provided at the feeder floor near each feeder for unloading of coal from bunkers on trucks at ground level. Each bunker outlet chute shall have arrangement for fixing a temporary chute for diversion of coal flow to the permanent emptying chute near each feeder. Two (2 nos.) temporary chute shall be provided for each steam generator for the above purpose. Necessary handling/ lifting arrangement and suitable platform & approach shall be provided for quick installations and removal of temporary chutes.

8.3.7 Suitable indicators shall be provided in the downspout between bunker and feeder to detect presence or flow of coal to ensure minimum seal height at inlet to RC feeder and trip the RC feeder if the level of coal tends to be below this seal height.

8.4 Raw Coal Feeders

8.4.1 Each mill shall be fed with coal by an independent coal feeder. All stipulations of NFPA (latest edition) shall be complied for feeders. In addition, the following features shall be provided:

i) Feeder type	Gravimetric, belt type with minimum size of 914.4 mm.
ii) Raw coal feeder	1.2 times the maximum capacity of coal pulverizer.
iii) Environment withstand capability	a) Ambient temperature : 50 ⁰ C (min.). b) Explosion pressure : 3.5 kg/cm ² (g) (min.). c) Other environmental conditions envisaged.



iv) Feeder accuracy	a) In-situ weighing accuracy : $\pm 0.5\%$. b) Repeatability : 0.1% . c) Shall have in-built facility for calibration.
v) "No coal" flow detection to be provided to stop the feeder when no coal is detected on the conveyor and when pluggage occur at feeder outlet. Paddle type coal alarm switch shall be provided for this purpose at the following locations: a) Over the feeder conveyor chain/belt : For indication of loss of coal flow to feeder. b) Near the feeder discharge : To stop the feeder in the event of coal pluggage at the feeder outlet.	

8.4.2 The feeder casing shall be designed to withstand an explosion pressure of $3.5 \text{ kg/cm}^2 \text{ (g)}$.

8.4.3 The feeder belt shall be of multiply reinforced rubber of single piece construction with arrangement for tracking and to prevent spillage.

8.4.4 Width of the belt shall have sufficient margin while operating in conjunction with the feeder inlet opening provided.

8.4.5 All RC feeder components coming in contact with coal (except belt) shall be made of stainless steel.

8.4.6 Facility for spraying water inside the casing shall be provided and provision for purge air to the feeder shall be made.

8.4.7 The feeder control system shall be microprocessor based. Coal weighing shall be automatic and shall include local & remote indication of rate of flow & totaliser counter.

8.5 Coal Pulverizers

8.5.1 Coal pulverizers shall be one of vertical spindle type classification. The pulverisers offered can be of Bowl or Roller or Ball & Race or equivalent type.

Each pulverizer shall supply coal to only one burner elevation.

8.5.2 Sizing of coal pulverisers

Selection, sizing and total number of coal pulverisers to be provided for each Steam Generator shall conform to following stipulations:

i) Number of mills for each steam generator	Adequate to achieve 100% TMCR for all specified coal(s) and all operating conditions, but not less than six (6) mills for 660 MW unit and eight (8) mills for 800 MW unit.
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ii) Number of standby mills	a) At 100% of TMCR, : One worst coal firing b) At 100% BMCR, : Nil worst coal firing c) At 100% BMCR, : One design coal firing
iii) Sizing of coal pulverizers confirming to clause (i) and (ii) above shall be under following conditions all occurring simultaneously: <ul style="list-style-type: none"> a) Maximum permissible mill loading for deciding mill capacity 90% or the mill loading achievable corresponding to the near worn out conditions of mill grinding rolls/balls/tyres etc. whichever is less. This condition shall be complied for the range of specified coals including the adequacy range of coals. b) Rated pulverized coal fineness at rated capacity of the pulverizer Not less than 70% thru 200 mesh (75 microns) and 98% thru 50 mesh (300 microns). c) Input coal size Upto 50 mm. 	

8.5.3 Classifier design

- i) Static/ dynamic classifier capable of maintaining rated conditions of fineness as specified under all conditions of operation, load changes and specified fuels shall be provided. Further, the classifier vanes shall be adjustable externally.
- ii) Fineness adjustment shall be possible while the mills are in service.
- iii) Outlet shall be of aerodynamic shape to prevent eddies. The classifier vanes and cones shall be lined with wear resistant material to ensure the guaranteed wear life.
- iv) In case of static classifier, provision for accommodating rotary classifier in place of stationary classifier in future shall be made in the mill/ boiler design. For this purpose, necessary structure, pulverized coal piping, spare piece etc. shall be provided.

8.5.4 Adequate vibration isolation of mills shall be ensured so that no adverse affects are transmitted to the nearby structure/installations.



8.5.5 Mill sound level shall not exceed specified values. While selecting lagging, background noise from adjacent mills, drive system and other secondary & stray noises shall be taken into account.

8.5.6 Seal air system

- i) 2x100% centrifugal seal air fans common for all the mills of one Steam Generator unit shall be provided.
- ii) The sealing system shall prevent ingress of any dust into the bearings and leakage of coal-air mixture to atmosphere.
- iii) Following margins shall be provided for each fan over and above the calculated values under maximum duty conditions as per specification requirements:
 - a) Margin on flow : 25%
 - b) Margin on pressure : 30%
- iv) Above margins shall be based on an ambient temperature of 50⁰C, relative humidity of 65 % and system leakages with mill operation at maximum duty.
- v) The seal air fan speed shall not exceed 1500 rpm under test block condition.
- vi) Seal air connections shall be provided at all locations including bearing, journals, feeders etc.
- vii) The seal air fans shall preferably be located at ground floor.

8.5.7 The design of lubrication system shall ensure continuous operation of mill bearings.

8.5.8 Mill gear box

Planetary type gearbox shall be provided. The gearbox design shall ensure that there is no ingress of coal dust into gearbox under all conditions of operation. The gearbox shall be guaranteed for trouble free operation of not less than 1,00,000 hours of operation of mill.

8.5.9 Mill motor capability

Minimum mill motor capability to restart the mill after a trip with mill full of coal shall be ensured. Such restart shall not call for any emptying of mills.

8.5.10 Each mill shall be fed with coal by an independent coal feeder.



8.5.11 Materials of construction

The material of construction of wear parts shall be selected taking into account highly abrasive nature of coal resulting from coal contamination with silica sand and Alpha-quartz as specified.

Mill component		Specification
i)	Classifier cone	Lined with minimum 15 mm thick ceramic tiles on both inside and outside surfaces of the cone
ii)	Grinding rings/ race	Material with hardness 550 BHN (min.) at surface (with adequate chilled depth)
iii)	Grinding balls/ rolls	Material with hardness 350 BHN (min.)
iv)	Minimum difference in hardness of rings/ rolls and race/ balls	100 BHN

8.5.12 Minimum guaranteed life of coal pulverizer wear parts

The guaranteed life of different mill components in "equivalent hours" of continuous mill operation at its rated capacity, while firing the specified range of coals and without requiring any in between repair or replacement shall be as under:

Item		Minimum life in equivalent hours
i)	Grinding elements (rolls/ balls and rings/ race)	7200 [See notes below]
ii)	Mill discharge valves	15000
iii)	Seals	20000
iv)	Classifier cone and other items lined with ceramic material	25000

Notes:

- The expected wear life of mill grinding elements (rolls/ balls and rings/ race) in equivalent hours, under conditions stipulated above shall be in the range of 7200 to 8000 hours.
- A curve indicating the variation in guaranteed wear life with variation in YGP index of coal fired (measured as per BS Standard BS-1016 Part-111) shall be furnished. Separate curves for different wear elements of mill shall be furnished e.g. for grinding rolls, grinding rings, clearly indicating its relationship with YGP index of coal.

8.5.13 Minimum mill turn-down ratio of 2:1 shall be ensured.



8.5.14 Tapping points shall be provided on each pulverized coal pipe at mill outlet for coal sampling as per ISO 9931.

8.5.15 One (1) no. Rota probe shall be provided for each steam generator for coal sampling as per ISO 9931.

8.5.16 Four (4) nos. Dirty Pitot tubes shall be provided for each steam generator for measurement of coal-air velocity in coal pipes.

8.5.17 Mill rejects system

- i) Mill reject system shall automatically discharge the tramp iron and other non grindable material through an outlet connection at a suitable height to a dense phase pneumatic conveying system.
- ii) Mill rejects collection & discharge system shall be designed to ensure sequential automatic operation of the coal mill discharge gates for flow of rejects into the reject spout.
- iii) The necessary mill isolation dampers/ valves, to facilitate automatic continuous or automatic intermittent discharge of rejects to the conveyor shall be provided.

8.5.18 Fire detection and extinguishing system shall be provided for the complete coal preparation & firing system including coal feeding system.

8.5.19 Lubrication of bearings & other parts shall be automatic and continuous.

8.6 Pulverised Coal Pipes

8.6.1 The design and arrangement of coal pipes shall ensure uniform distribution of primary air and pulverized coal between all burners served by one pulverizer under all conditions of loading.

8.6.2 Fuel air mixture velocity in coal pipes: minimum- 15 m/sec and maximum- 28 m/sec.

8.6.3 The coal air mixture velocity in the coal pipes shall not be lower than the critical fallout velocity under all conditions of mill operation from start up of boiler onward.

8.6.4 The pipes shall be designed for an explosion pressures of 3.5 kg/cm² (g) (minimum).

8.6.5 Maximum permissible design stress shall be yield stress or 0.2% proof stress.

8.6.6 The piping system shall be designed for a continuous operating temperature of 110⁰C (minimum).



- 8.6.7 Calculated static loading of each support of the PC pipes shall be increased by at least 25% to arrive at the design load, to take care of the shock loading occurring in the pipe work under abnormal conditions of operation.
- 8.6.8 The guide plates, wherever provided in the coal pipe, shall be removable, and access to them shall be obtained through detachable cover. The guide plates shall be made up of suitable abrasion resistant material.
- 8.6.9 Coupling and toggle section arrangement for fuel piping shall be provided to take up the furnace expansion.
- 8.6.10 The following PC pipe portions shall be ceramic lined with ceramic thickness of not less than 15 mm:
- i) From mill outlet to first bend and two times pipe diameter straight length down stream of first bend.
 - ii) All bends between 15⁰ & 30⁰ angle and straight length downstream of the bends equivalent to one pipe diameter.
 - iii) All bends of 30⁰ and higher angle and two times diameter straight length downstream of the bend.
 - iv) The burner inlet elbow and the pipe piece after the elbow. PF pipe from mill to the classifier (in case of separate classifier).
- 8.6.11 The pipe/ bend base material thickness, wherever ceramic liners are provided, shall not be less than 8 mm.
- 8.6.12 The straight unlined PC pipe length shall be of mild steel having a thickness not less than 13 mm with a minimum wear allowance of 4 mm.
- 8.6.13 Ceramic material shall be Alumina content of not less than 90% and guaranteed life 25000 hrs (minimum).
- 8.6.14 Suitable devices shall be provided in each pulverized coal pipes to enable on-load adjustment for equalizing flow.
- 8.6.15 Purge air connections shall be provided after the mill outlet valve to clean pulverized coal pipes of any deposits etc.

8.7 Coal Burners

8.7.1 Coal burner design

- i) Turn down ratio of coal firing system 2:1 (minimum).



- ii) The coal burner design shall ensure a steady log mean density of coal air mixture distribution as it enters the combustion zone without allowing the coal dust to settle down.
 - iii) The burner design shall minimize erosion. The burner shall be designed to ensure smooth variation in the fuel flow without affecting the air fuel ratio.
 - iv) The air/fuel ratio around the burner shall be optimized to ensure low emission of NO_x. Total NO_x emission (fuel as well as thermal) shall not exceed 260 gms/ Giga Joule of heat input of the boiler at 6% O₂ level.
 - v) Burners shall be provided with centralized automatic control with flame scanner and safety protection.
- 8.7.2 Each coal burner shall be served by one separate coal pipe and shall be provided with one knife edge type gate valve at mill outlet. The valve shall be electrically/ pneumatically operated and hooked up to burner management system (BMS).
- 8.7.3 Compartmented wind box shall be provided for supply of secondary air for combustion.
- 8.7.4 The material and construction of burner shall withstand radiation from the furnace, when not in use and shall not get damaged.
- 8.7.5 Parts subjected to high temperature, which cannot be protected by other means, shall be made of alloy steel.
- 8.7.6 Air register (if applicable) construction shall be such that:
- i) The tangential air vanes are always free to move.
 - ii) The support bearings shall be preferably located outside. In case the support bearings are located inside, minimum period of operation shall be 16000 hrs without calling for any type of maintenance during this period.
- 8.7.7 The angle at confluence between the coal burner primary air and secondary air shall be such that the inherent carbon monoxide produced is removed by scrubbing action without any significant reduction in velocities of the air stream.
- 8.7.8 Minimum operating life of burner parts without requiring any maintenance and replacement shall be 8000 hrs.
- 8.7.9 Burner shall be removable or replaceable from outside the steam generator without entry to the furnace.



8.8 Primary Air Fans

8.8.1 Fan design

- i) Type of fan : Two stage, constant speed, variable pitch, axial type.
- ii) No. of fans per unit : Two
- iii) Type of fan blade : Streamlined/ aerofoil bladed type designed to withstand high bending and axial load.
- iv) Fan suction : From atmosphere
- v) Fan rotational speed : 1500 (maximum)

8.8.2 Fan sizing criteria

- i) Each fan shall be rated to meet requirement of 60% BMCR load (one stream in operation) with following conditions all occurring together.
 - a) Worst coal firing with maximum moisture content.
 - b) Power supply frequency- 47.5 Hz.
 - c) Ambient air temperature- 50⁰C & RH 65%.
 - d) Air-heater air-in-leakage- 15% or guaranteed whichever is higher.
- ii) In any case the margins on flow & pressure shall not be less than 25% and 30% respectively over the calculated values at 100% BMCR condition. Above margin shall be under conditions indicated below all occurring together:
 - a) Worst coal firing with maximum moisture content.
 - b) Power supply frequency- 50 Hz.
 - c) Ambient air temperature- 50⁰C & RH 65%.
 - d) Air-heater air-in-leakage- 15% or guaranteed whichever is higher.
 - e) All mills including standby mill shall be in service.

8.8.3 Fan characteristics

- i) Shall be compatible with pulverized coal system resistance and boiler operation at rated loads, during boiler start up & low load operation with minimum number of mills.



- ii) The system resistance curves shall always be sufficiently below the fan stall line.
- iii) Best efficiency point shall be close to 100% TMCR operating point of fan.

8.8.4 Fan control system

- i) Fan flow control shall be by blade pitch control. The final control element shall be electrically/ pneumatically operated.
- ii) The system shall be capable of working on automatic mode for all regimes of operation in a steady and stable manner.

8.8.5 Primary air flow measurement

Primary air flow measuring devices as per OEM's proven design shall be provided at air inlet to each mill as well as at the suction of each fan. PA fan inlet flow measurement shall be provided using fan inlet elbow. However, if such an arrangement is not possible, flow element (venturi/ aerofoil system) shall be provided with three pair of tapping points at suction of each PA fan. Necessary tapping points for temperature compensation in the flow measurement shall also be provided.

8.8.6 Material of construction

i)	Fan blades	High strength Aluminium alloy with minimum hardness of BHN-75.
ii)	Base plate	Base plate - cast iron or welded steel.
iii)	Casing	Sheet steel of suitable thickness.
iv)	Fan inlet box, diffuser & intermediate pieces	Sheet steel of thickness not less than 6.00 mm.

8.8.7 Fan bearing lubrication system

- i) The rotor assembly shall be supported over an oil lubricated bearing assembly consisting of antifriction/sleeve bearing adequately sized to take care of radial thrust loads.
- ii) For mounting of vibration pads/ pickups, flat surfaces shall be provided both in X and Y directions, on the bearing housing.
- iii) In case of oil lubricated bearing the design shall be such that bearing are lubricated by external oil lubricating system in which oil is cooled by external cooler.
- iv) Duplex RTDs (100 ohm at 0⁰C) and temperature indicators shall be provided for each bearing as per standard practice of the OEM for local as well as remote monitoring of bearing metal temperature.



CHAPTER 9

FUEL OIL FIRING SYSTEM

9.1 General

Fuel oil preparation and firing system shall comprise of heavy fuel oil (HFO/LSHS/HPS) firing system and light diesel oil (LDO) firing system.

9.1.1 Heavy fuel oil firing system

Heavy fuel oil (HFO) shall be used for initial start-up, low load operation and as secondary fuels for pulverized coal flame stabilization at the startups/ low load operation. The fuel oil shall be drawn from HFO storage tank(s) of common storage for both the units by fuel oil pressurizing pumps and pumped through steam oil heaters. The oil shall be taken in steam generator unit(s) and recirculated back to the storage tank(s) through oil coolers. The oil requirement of oil burners of the Steam Generator shall be tapped off from a ring main formed at the respective Steam Generator area. The oil pressure shall be maintained to the required value in the pressure main by means of automatic pressure regulating valve(s). Oil temperature shall be controlled by regulating steam flow to fuel oil heaters. All facilities required for functioning of fuel oil supply to the burners under all operating conditions shall be incorporated in the design. Between pressure oil line and return oil line of each steam generator, an interconnecting line shall be provided with automatic control system to maintain the pressure of the oil to the steam generator at a predetermined value. Steam tracing shall be provided for HFO supply and return lines.

9.1.2 LDO firing system

LDO firing system shall be used for cold start up of steam generators, generation of auxiliary steam using auxiliary boiler (if applicable) and for flushing of heavy fuel oil lines. Basic scheme for LDO system shall be the same as that discussed above for heavy fuel oil system, except that there shall not be any heating requirements. LDO system including pumps, piping, valves etc. shall be sized to facilitate simultaneous cold/black start of both the units.

9.1.3 Fuel oil drain system

The fuel oil drains from different equipments and piping etc. of a steam generator shall be brought by gravity to a common drain oil tank provided for each steam generator. The oil collected in this tank shall be periodically pumped back to the fuel oil storage tanks. Drains from the oil pressurizing pump house and common oil piping shall be taken by gravity to one common drain oil tank in the pump house area and pumped to fuel oil storage tanks.



9.1.4 Fuel oil condensate system

Condensate from complete fuel oil plant shall be brought to a common condensate flash tank in fuel oil unloading area. Drain from this condensate tank shall be connected to nearest station drain.

9.1.5 Oily water drain system

The oily waste water drains from each steam generator area shall be collected and suitably treated in an oil separator. The treated outlet water shall not have oil content more than 10 ppm. The recovered oil from oil separators shall be led to drain oil tanks/ waste oil collection tanks. Separated water shall be pumped to effluent treatment plant (outside BTG area) using sump pumps.

9.2 Fuel Oil Preparation and Firing System

9.2.1 The fuel oil preparation and firing system shall be sized based on following criteria:

Description		Requirement	
		Heavy oil firing	LDO firing
i)	Purpose of fuel oil firing	Initial start up, coal flame stabilization at start up/ low load.	To facilitate cold start up of unit.
ii)	Type of fuel oil	Heavy fuel oil (HFO/ HPS/ LSHS).	Light diesel oil (LDO).
iii)	Oil firing system capacity	To cater to 30% BMCR requirements of steam generators without any coal firing.	To cater to 7.5% BMCR requirements of steam generators without any coal firing.
iv)	Oil firing system configuration	Common for all steam generators.	Common for all steam generators.

9.2.2 Design/ sizing of various pump shall be based on following criteria:

Design criteria		Requirements			
		HFO pumps	LDO pumps	Drain pumps	Sump pumps
i)	Type of fuel oil to be handled	HFO/HPS/ LSHS	LDO	HFO/HPS/ LSHS	Oil & water
ii)	Pump suction temp.	Oil pour point temperature	Ambient	Oil pour point temperature	Ambient
iii)	Max. temp. of fuel oil to be handled	90 ⁰ C	Atmospheric	90 ⁰ C	50- 85 ⁰ C



iv)	Pump design/ construction code	HIS, ASTM, ASME or equivalent			
v)	No. of pumps	One working for each SG plus one common standby	2(1W*+1S)	2(1W+1S) for each drain oil tank	2(1W+1S) for each sump
vi)	No. of oil heaters	One working for each SG plus one common standby	-	-	-
vii)	Capacity of each pump	To cater to 30% BMCR requirement of one steam generator without coal firing plus 10%	To cater to 7.5% BMCR requirement of one steam generator without coal firing plus 10%	4 m ³ /hr	10 m ³ /hr
viii)	Pump suction head	considering zero tank level	considering zero tank level	considering zero tank level	-
ix)	Pump discharge head	To suit the requirements of burners.	To suit the requirements of burners.	25 mlc (minimum) or as required to pump oil from drain to main oil storage tank @ 4m ³ /hr, whichever is higher.	50 mlc (minimum) or suiting site requirements whichever is higher.

* One additional working pump for more than two units

9.2.3 The fuel oil pressuring pumps, LDO pressuring pumps and drain oil pumps shall be rotary, positive displacement, horizontal type fitted with relief valves.

9.2.4 Heavy fuel oil heaters shall be:

- i) Shell and tube type with oil through tubes (oil through shell is also acceptable).
- ii) Capacity of each heater shall be suitable for the rated capacity of each heavy fuel oil pressurizing pump.



- iii) Heater inlet fuel oil temperature for design shall be considered as 30⁰C.
- iv) Heater outlet temperature shall be suitable for the viscosity requirements at the fuel oil burner tips for the grade of oil (HPS/HFO/LSHS) used.
- v) Maximum metal temperature of heater heat transfer surface shall be 210⁰C (maximum).
- vi) Heater design/ construction shall be according to TEMA, ASME Boiler and pressure vessel code, HEI, USA. Pipe connections to heater shall be as per TEMA class C BEV type.
- vii) Heater tubes shall be seamless.

9.2.5 Filters

- i) Following filters shall be provided in the HFO line:
 - a) Coarse filters at each pressurizing pump suction.
 - b) Fine filter at each oil heater outlet in fuel oil pump house.
 - c) Fine filter in the oil line in boiler area supplying oil to the burners.
- ii) Maximum oil pressure drop across each filter shall be 0.1 kg/cm² when filter is clean and 0.3 kg/cm² when filter is 50% clogged.
- iii) Aperture size for fine filter shall not exceed 108 micro meter or at least 30% smaller than smallest oil orifice or passage to the burners.
- iv) Material of filtering mesh shall be stainless steel.

9.2.6 Trip and nozzle valves

- i) Heavy fuel oil and light diesel oil trip valves and nozzle valves shall be suitable to handle oils at temperature/pressure required at the burners. Further, these valves shall confirm to ANSI leakage Class-VI under shut off pressure conditions of respective pumps.
- ii) The solenoid valves for heavy fuel oil & light oil trip valves and individual burner nozzle valve shall be:
 - a) Of single coil heavy duty construction having class 'H' insulation with closing time less than one (1) second.
 - b) De-energized/ air fail to close type.
- iii) Operating voltages for trip valve solenoid & nozzle valves solenoid shall be 24 Volts DC or 220 Volts DC.



9.2.7 Oil burners

Description		HFO firing system	LDO firing system
i)	Type of burner	Steam atomized	Air atomized
ii)	Burner cooling medium	Steam or air	Air
iii)	Burner tip material	Resistant to corrosion due to fuel oils containing sodium, vanadium, sulphur, chloride etc.	Resistant to corrosion due to oil containing sodium, vanadium, sulphur, chloride etc.
iv)	Minimum life of burner tips, before needing any maintenance/ replacements	8000 hours	8000 hours
v)	Hardness of atomizer (the hardness to be retained even at 400 ⁰ C)	Minimum vickers hardness number of 400	Minimum vickers hardness number of 400
vi)	Type of oil igniters	High energy arc igniters	High energy arc igniters
vii)	Oil burner turn down ratio	4:1	4:1

9.2.8 The design of fuel oil system shall ensure that compliance with the following operational requirements:

- i) Facilities for auto start of standby HFO/ LDO pressuring pumps in event of tripping of any running pump or low fuel oil pressure.
- ii) Facility for auto start and shutdown of drain oil pumps in conjunction with level in the drain oil tanks.
- iii) Facility for automatic as well as manual start/ignition of oil burners (in association with BMS).
- iv) Maximum turn down ratio, for the oil burners (without needing burner tip changes).
- v) Automatic purge interlock to facilitate restarting of oil firing system after trip /prior shut down of oil firing.



- vi) Separate flame viewing opening/facility for boiler operation and for flame monitoring at each burner from out side of the boiler. Provision shall be made to keep the viewing heads cool below 75⁰C and to keep optical system clean during firing/non firing by pressurized air.

9.2.9 Piping, fitting and valves in fuel oil (HFO & LDO) firing system

- i) The piping in fuel oil firing (HFO & LDO) shall conform to following codes:

a)	Steam & condensate piping below 20 kg/cm ² pressure	IS 1239 (heavy duty) or ASTM- A- 106 Gr. B or equivalent.
b)	Fuel oil piping	1. API-5L GR B or ASTM-A-106 Gr. B (before pressurizing pump). 2. IS1978 or equivalent (from discharge of pressurizing pump to boiler).
c)	Piping/ valve sizing	1. Heavy oil: HFO piping system of each steam generator shall be sized to meet the fuel oil requirement of the unit for operation at 30% BMCR load. 2. Light oil: LDO piping system of each shall be sized to meet the fuel oil requirement of the unit for operation at 7.5% BMCR load.

- ii) Piping and fittings shall be of carbon steel butt welded connection (where possible) conforming to ASTM-A 234 (or approved equivalent standard). All the flange connections shall conform to IS:6392 (or approved equivalent standard) and shall be suitable to withstand design conditions of system, to which they are connected.
- iii) Valves for oil services shall be plug type/ ball type, leak proof, fire safe as per the requirement of API 6FA. Material of valves on oil lines shall be Cast Iron on pump suction side and Cast Steel on pump discharge side.
- iv) One no. of HFO cooler of adequate size alongwith its 100% bypass per unit shall be provided on the heavy fuel oil return line for cooling of the return oil to the temperature of oil in the fuel oil storage tanks. The cooler shall be complete with all connecting piping, valves, supports etc. for HFO oil as well as cooling water. It shall be located in the FO pressurizing pump house area.
- v) Facility shall be provided for complete flushing of heavy fuel oil handling system by LDO. For LDO handling system, steam flushing system shall be provided for cleaning during commissioning.



CHAPTER- 10

ELECTROSTATIC PRECIPITATOR

10.1 Design Data

The electrostatic precipitator(s) (ESP) of each unit shall be arranged in minimum four (4) independently operating gas streams (casings) for 660 MW unit and six (6) independently operating gas streams (casings) for 800 MW unit. Each gas stream/ casing shall be provided in twin compartments. ESP shall be designed to comply with the requirements stipulated under 'guarantee point' and 'design point' in the table below:

Sl. No.	Item	Guarantee point	Design point
i)	Unit loading	100% TMCR	100% BMCR
ii)	Type of coal	Design coal	Worst coal (maximum ash coal from range)
iii)	Ambient air condition	27 ⁰ C temp. and 60% RH	45 ⁰ C temp. and 60% RH
iv)	Gas flow per steam generator at the ESP inlet when firing respective coal (m ³ /sec)	To be worked out when firing the specified design coal at TMCR.	To be worked out when firing the specified worst coal with max. ash at BMCR load, considering 25% excess air at economiser outlet, 15% air heater in leakage and 2% duct.
v)	Gas temperature at ESP inlet (⁰ C)	125 ⁰ C or as predicted under conditions stipulated above, whichever is higher.	140 ⁰ C or as predicted under conditions stipulated above, whichever is higher.
vi)	Inlet dust burden (gm/Nm ³)	To be worked out based on 85% of ash or actual predicted whichever is higher being carried forward to ESP while firing specified design coal.	To be worked out based on 85% of ash or actual predicted whichever is higher being carried forward to ESP while firing specified worst (maximum ash) coal.
vii)	No. of electrical fields out of operation	One each in all the passes	One each in all the passes
viii)	Outlet dust burden (mg/Nm ³)	50 mg/Nm ³ (maximum) or as per MOEF's requirement whichever is more	80 mg/Nm ³ (maximum) or as per MOEF's requirement whichever is more



		stringent with one field out of service in each pass.	stringent with one field out of service in each pass.
ix)	ESP dust collection efficiency (%)	To be worked out corresponding to outlet dust burden and inlet dust burden as above.	To be worked out corresponding to outlet dust burden and inlet dust burden as above.
x)	Minimum specific collection area (sca) with one field out of service in each pass ($m^2/m^3/s$)	-	260*
xi)	Spacing between the collecting plates (centre line to centre line) transverse to the gas flow (mm)	300*	300*
xii)	Maximum flue gas velocity through the ESP (m/s)	1.0	1.0
xiii)	Treatment time of the flue gases (seconds) minimum	20	20
xiv)	Other design parameters:		
	a) Minimum aspect ratio	1.5	1.5
	b) Design internal pressure at 67% yield strength (mmwc)	± 660	± 660
	c) Short term excursion temperature (for approx. thirty (30) minutes at a time) ($^{\circ}C$)	300	300
	d) Minimum no. of transformer rectifier (TR) sets per stream per series electrical field	One (1)	One (1)
	e) Maximum collection area served by one TR set (m^2)	5000	5000
	f) Minimum no. of bus sections per TR set	One (1)	One (1)



g) Minimum dust hopper storage capacity (upto the maximum trip level based on design point conditions (while firing worst coal (with maximum ash) (in hrs)	-	eight (8)
h) Minimum hopper valley angle to the horizontal (degrees)	Sixty (60)	Sixty (60)
i) Maximum nos. of ash hoppers	Two (2) for one TR set	Two (2) for one TR set

* Collecting plate spacing of 400 mm may also be allowed with reference minimum sca as $195 \text{ m}^2/\text{m}^3/\text{s}$ (calculated from sca of $260 \text{ m}^2/\text{m}^3/\text{s}$ for 300 mm spacing as per inverse proportion of spacing between collecting plates).

10.2 System Description

The ESPs shall be of outdoor type and installed on the cold end side of regenerative air pre-heaters. The flue gas shall be drawn from air pre-heater outlets and guided through adequately sized duct work into the specified number of independent gas streams of the ESP. Similarly, the flue gas after the ESP shall be led to the suction of the induced draft fans. The flue gas temperature may approach the economiser outlet temperature in case the regenerative air pre-heaters fail to operate. These aspects shall be taken into account while designing the ESPs.

10.3 Service Conditions

The steam generators are to be designed to burn HFO/HPS/LSHS and LDO in conjunction with pulverised coal during startup and at low loads for warm up and flame stabilisation. Further, the frequency and durations for startup and low loads operation may be quite large during unit commissioning and first year of operation. The entire characteristics of expected combination of fuels to be fired shall be taken into account and preventive measures shall be provided to minimise the possibility of fires in the ESPs and to avoid the corrosion of ESP components/ surfaces.

10.4 Location and Layout Requirements

ESP control room shall be located at grade level adjacent to the ESP and shall house the control cubicles. The Man Machine Interface (MMI) to be provided to enable unit control room operator to access the ESP controls for control, monitoring and data acquisition functions may be suitably located in the unit control room.



10.5 Maintenance Requirements

- 10.5.1 The design of the precipitators shall allow adequate space above and between the adjacent fields to carryout necessary inspection and maintenance. A permanent walkway shall be provided at each rapper level both for the discharge and collecting plates.
- 10.5.2 Minimum 2.0 m wide platforms shall be provided between the two casings of the ESPs to facilitate maintenance work and minimum 1.2 m wide platform shall be provided all around all ESP passes at intermediate and TR set elevation. The protection for the platform and the rapping motors from exposure to rain shall also be provided.
- 10.5.3 One staircase of minimum 0.85m clear width shall be provided between two adjacent streams (casings) from ground to the roof of the ESPs with landings connected at all platforms. As such, minimum three (3) staircases shall be provided for ESP of 660 MW unit and five (5) staircases for ESP of 800 MW unit. Two adjacent staircases shall be located on opposite ends of the ESP. Further, the platforms between all the ESP casings shall be interconnected at least at one intermediate elevation.
- 10.5.4 Each compartment of individual stream of ESP shall be provided with isolation dampers at inlet and outlet for carrying out maintenance work while the remaining streams of ESP are in service by completely isolating it electrically and grounding it. Suitable safety interlocks etc. shall be provided.
- 10.5.5 A monorail system with movable trolley and an electrically operated hoist mounted on the precipitators roof shall be provided for handling and maintenance of TR sets, rapper motors, fans (if applicable) etc. By this arrangement, it shall also be possible to lower the TR sets down to the ground level and/or onto a truck. Normal and special maintenance tools shall also be furnished for attending to different equipment.

10.6 Model Study

Computer based model study using CFD technique or physical flow model study shall be carried out to achieve optimum size and layout of the ducting, uniform flue gas distribution, maximum particulate collection, minimum draft loss, minimum dust drop out and build up and minimum re-entrainment from within the precipitator. The design of the duct work, guide vanes, flow splitters etc. shall be finalized based on results of the model study. The model study shall also include a gas distribution study for the duct system around ESP to find out the effect of isolation of one stream of the ESP. CFD model study or physical flow model study for the ESP may not be needed in case the same has been earlier carried out for similar size and type of the ESP.

10.7 Gas Distribution System

Gas distribution system shall be provided at the precipitator inlet as well as outlet sections to achieve uniform gas distribution throughout the ESP with



maximum utilisation of collection areas at the inlet and outlet. It shall be designed to minimise local velocity regions and to avoid bypassing and re-entrainment of dust. To achieve the above, internal baffles etc. shall be provided. The distribution screens shall be of modular design.

10.8 Collecting Plates (electrodes)

Collecting plates shall be designed for dimensional stability and to maintain the collection efficiency at the specified level. The specific collection area shall in no case be less than the value specified. The profile of the collecting plate shall be such as to minimise the re-entrainment of collected dust at the time of rapping. Minimum plate thickness shall be 18 BWG/1.2 mm. Each plate shall be shaped in one piece construction and shall be stiff enough to carry the rapping intensity. The swaying and warping tendencies shall be prevented by suitable means.

10.9 Discharge Electrodes

The high tension discharge electrodes shall be of rigid frame type design, located mid-way between the collecting plates. The electrodes shall be self tensioned, or restrained in pipe frames. They shall be constructed from durable, corrosion and erosion resistant material. In case spiral type discharge electrodes are being offered, the material for the same shall be UHB 904 L or approved equivalent. Vertical and horizontal members shall be rigid enough to maintain the alignment of the system without warping or distortion even at elevated temperatures. Provisions shall be made to maintain alignment of electrodes during normal operation, including rapping and thermal transients. However, no anti sway insulators shall be used at the bottom of the discharge electrodes frame to accomplish the above.

10.10 Rapping System

10.10.1 Independent rapping system shall be provided for discharge electrodes and collecting plates with control systems as per the requirements specified. The rapping mechanism shall be of either electric impact type or tumbling hammer type. This shall be adjustable in frequency, intensity (for electric impact type only) and frequency (for tumbling hammer type) to provide an efficient cleaning rate. Separate rapping equipment, shall be provided for the discharge and collecting plates served by one TR set so that each mechanism can be suitably adjusted when required. It shall be so arranged that the rapping frequency can be independently set from the control room in accordance with the operating requirements. The rapping frequency range shall be adjustable in wide range and this facility shall be such that it does not require any stoppage of rapper operation. Sufficient number of rappers and rapper drives shall be provided so that minimum collection area and discharge electrode lengths are rapped at a time, which shall not be more than 6% of the total collection area for at least the last two fields/discharge electrode length of each field served by one TR set. The rapping system shall be designed for continuous sequential rapping to prevent puffing under any conditions of precipitator operation.



- 10.10.2 A minimum rapping acceleration of 75 g measured normal to the plane of the plate shall be imparted on all parts of all the collecting plates.
- 10.10.3 The perforated plates and/or guide vanes furnished for gas distribution system shall also be provided with rapping systems. The rapping mechanism shall produce sufficient force to keep the perforated plates/guide vanes clean.

10.11 Dust Hoppers

- 10.11.1 Dust hoppers shall be of pyramidal type or conical. Each having a storage capacity of minimum of eight (8) hours corresponding to the maximum ash collection rate of the field under which the hopper is being provided when two preceding fields are de-energised. The hopper capacity shall be based on the inlet dust burden, gas flow rate and gas temperature specified for the design point condition while firing the maximum ash coal. Storage shall be upto a level that will not reduce the overall efficiency of the precipitator due to re-entrainment. Ash storage capacity shall be at least 10% higher than the ash storage capacity theoretically required for each dust hopper. Specific weight of ash shall be assumed as 650 kg/m³ for calculating storage capacity and 1350 kg/m³ for structural design. Further, for hopper strength and ESP structural calculations, the level of ash in ESP shall be considered atleast upto the top of hopper partition plane or the bottom of plates (whichever is more). The number and arrangement of dust hoppers shall be such that there is at least one dust hopper per TR set. The hoppers for all fields shall be identical in shape and size.
- 10.11.2 Hoppers shall be in welded steel plate construction. The lower 1.5 meters of each hopper shall be lined with 16 gauge or heavier stainless steel 304 sheet/plate. All hopper internal sloping corners shall have 100 mm radius. Hopper valley angle to the horizontal shall not be less than sixty (60) degrees. Hopper outlet flanges shall be terminated at a height of 3.5 meters above the ground level to facilitate installation of fly ash removal system.
- 10.11.3 The dust hoppers shall be electrically heated upto a minimum of lower one third (1/3) of the dust hopper height but not less than 1.5 meter in height by thermostatically controlled panel type heating elements to prevent ash bridge formation. The heaters shall be capable of maintaining internal hoppers temperature of 140⁰C or the gas temperature whichever is lower. Maximum excursion of flue gas temperature upto 300⁰C, while the air heaters are out, shall also be considered for heater mechanical design.
- 10.11.4 Each hopper shall be provided with two (2) nos. of 100 mm dia poke hole in opposite directions, with threaded caps. The caps shall have flat iron bars suitable for striking with a hammer, to assist in breaking free any seized threads. The hoppers shall also be provided with suitably designed and located rapping anvils for loosening the fly ash by striking with sledge hammer.



- 10.11.5 Each dust hopper shall be provided with a high level and a low-level dust level monitor operating on proven radio frequency measurement principle. The level monitoring system shall incorporate all the necessary accessories including two nos. level switches per hopper (one for high and other for low level), each with 2 NO + 2 NC contacts, local and remote signaling lamps and high and low level alarms. The logic shall also have provisions to de-energise the TR set of the particular field of the affected ash hopper, if corrective action is not taken. The level control device shall be unaffected by ash build up, due to moisture or charged ash on either the hopper walls or on the probe itself.
- 10.11.6 Each hopper shall be provided with a quick opening access door of not less than 600 mm dia, if round or not less than 450 mm x 600 mm, if rectangular. Access doors shall be hinged vertically and provided with a safety chain and grounding strap. Suitable access ladders shall be provided from the walkway beneath the hoppers to facilitate approach to the access doors.
- 10.11.7 The hopper outlet shall not be less than 350 mm x 350 mm.

10.12 Casing

- 10.12.1 Each of the ESP streams shall be housed in its own separate casing. The space provision shall be kept for installation of one additional field in all streams of the ESP in future, if required.
- 10.12.2 The precipitator elements shall be enclosed in gas tight, weather proof, and all welded reinforced steel plates. Sway bracing, stiffener and other local members shall be incorporated into the shell construction. The precipitator casing shall be fabricated from all welded reinforced, 5 mm minimum thickness, carbon steel plates conforming to ASTM A36/ IS-2062. The exposed surfaces shall be self-draining and seal welded to prevent ingress of moisture during monsoon.
- 10.12.3 The precipitator casing and its elements shall be designed to withstand a pressure of ± 660 mmwc at 67% of yield strength and a temperature of 200°C. The casing shall also be able to withstand excursion temperature upto 300°C that may persist for upto thirty (30) minutes on account of air pre heater failure. Adequate provision shall be made to accommodate thermal expansion and movements as required by the arrangement and operating conditions. In order to prevent distortions, the structural design shall take care of unequal expansions.
- 10.12.4 The precipitator casing and hoppers shall form a common structure reinforced to withstand the wind load (in accordance with IS: 875) and load due to dust storage in the hoppers etc.
- 10.12.5 Access door of quick opening type, shall be provided to allow entry to all sections of the precipitators for maintenance and access. The design shall be such as to eliminate air-in leakage through the doors.



10.12.6 The precipitator shall be guided, anchored or supported by lubricated plates/roller bearings at such locations as may be required to limit precipitator, ductwork or expansion joint forces or movement. Each casing shall be restrained to grow in a radial direction from the anchor point. In case lubricated plates are used these shall be covered under all conditions of precipitator movements by 1.6 mm thick type 306 stainless steel plates.

10.13 Penthouse Covering

The TR sets/ electrical equipments placed on ESP roof shall be adequately covered for weather protection with corrugated GI/ Metapoly sheets.

10.14 Thermal Insulation

Thermal insulation and cladding shall be provided conforming to requirement as stipulated elsewhere in the document.



CHAPTER – 11

VOID



SECTION-3

*STEAM TURBINE
GENERATOR &
AUXILIARIES*



CHAPTER - 12

STEAM TURBINE

12.1 General

12.1.1 Type

The steam turbine shall be tandem compound, single reheat, regenerative, condensing, multi-cylinder design with separate HP, separate IP and separate LP casing(s) OR combined HP-IP and separate LP casing(s), directly coupled with generator suitable for indoor installation. HP turbine shall be of double casing design. HP inner cylinder, IP cylinder and LP cylinder(s) shall be horizontally split.

12.1.2 Rating

The steam turbine generator unit shall conform to the following design and duty conditions:

- i) Output under turbine maximum continuous rating (TMCR) at generator terminals : 660 or 800 MW, as applicable.
- ii) Turbine throttle steam pressure (minimum) : 247 kg/cm² (abs).
- iii) Turbine throttle main steam temp. (minimum) : 565⁰C.
- iv) Reheat steam temp. at turbine inlet (minimum) : 593⁰C.
- v) Maximum turbine cycle heat rate at 100% TMCR, 33⁰C, 0% make up with TD-BFPs : 1850 kcal/kWh.
- vi) HPT exhaust pressure : To be selected by the turbine manufacturer as per optimisation of turbine cycle.
- vii) Design & operational requirement including variations in rated steam temperature & pressure : As per IEC 45 except as for specifically indicated in the document.
- viii) Pressure drop in reheat circuit i.e. between HP turbine exhaust & IP turbine inlet : Maximum 10% of HPT exhaust pressure.



- ix) Cooling water temperature at inlet to condenser : 33⁰C¹
- x) Maximum design condenser pressure : 77 mm Hg (abs)²
- xi) Turbine speed : 3000 rpm.
- xii) Frequency variation range around rated frequency of 50 Hz : (-) 5% to (+) 3% (47.5 Hz to 51.5 Hz).
- xiii) DM water make up to thermal cycle under TMCR condition : 1% of throttle steam flow.
- xiv) Final feed water temp. for Heat Rate guarantee point & TMCR condition : To be selected by the turbine manufacturer as per optimisation of turbine cycle.
- xv) Turbine protection against water induction : As per ASME-TDP-I, Latest edition.

The Turbine maximum continuous rating (TMCR) output shall be achieved at generator terminals after deducting all electrical power used for excitation, turbine generator control, lubrication, generator cooling and sealing, turbine gland steam exhauster, turbine generator main oil tank vapour extractor and any other such integral auxiliary of turbine generator under rated steam conditions with heat cycle makeup of 1% of throttle steam flow, all extractions in operation and design condenser pressure.

Note:

- a) "Throttle/main steam conditions" means initial/main steam conditions (i.e. pressure, temperature and flow) at inlet to main steam strainer.
- b) "Reheat steam conditions" means reheat steam conditions (i.e. pressure, temperature and flow) at inlet to reheat steam strainer.

12.1.3 Other features

- i) Turbine shall be capable of operating continuously with valves wide open (V.W.O.) to swallow at least 105% of TMCR steam flow to the turbine at rated main steam and reheat steam parameters and also the corresponding output shall not be less than 105% of rated load with 0% make up and design condenser pressure.

Overload valve (HP stage bypass) to meet the above specified VWO requirement is also acceptable, if it is a proven practice of the Turbine

¹ 30⁰C for sea water based once through type CW system

² 60 mm Hg (abs) for sea water based once through type CW system



manufacturer. In such case VWO shall mean wide open condition of the turbine main control valves and the overload valves.

- ii) The turbine- generator set shall be capable of continuous TMCR output under rated steam conditions, 89 mm Hg (abs)³ condenser pressure, 1% make-up and 47.5 Hz grid frequency.
- iii) The steam turbine generator unit shall be suitable for direct connection to steam generator having no inter connection with other units either on the boiler feed water side or main steam side.
- iv) The steam turbine shall have preferably seven uncontrolled extractions for regenerative feed heating based on optimized cycle and shall be suitable for satisfactory operation under tropical conditions. The cycle shall consist of minimum 3 nos. of HP heaters with extraction for top HP heater from HP turbine, one no. of deaerator and minimum 3 nos. of LP heaters.

12.1.4 Operational capabilities

- i) *Overpressure Operation (if applicable):* Turbine overpressure capability (under VWO) shall be indicated along with corresponding continuous output of TG set. The Turbine shall be capable of accepting variation in steam pressure as per IEC-45.
- ii) *HP Heaters Out of Service:* Turbine shall be capable of continuous operation under all HP heaters out of service with maximum output not less than rated output.
- iii) *Variable Pressure Operation:* Turbine shall be capable of operating on variable pressure mode during part load and start-up operation.
- iv) *Two Shift & Cyclic Load Operation:* The Turbine shall be suitable for two-shift operation & cyclic load variations.
- v) *Fast Start- up and Loading/ Unloading Rate:* The TG set shall be capable of being started from cold condition to full load operating conditions in as short time as possible. The TG set shall be designed for minimum rate of loading/ unloading mentioned below without compromising on design life of the machine:
 - a) Step load change : Minimum $\pm 10\%$ to facilitate fast loading/ unloading of the unit.
 - b) Ramp Rate : Minimum $\pm 3\%$ per minute above 30% load.

³ 70mmHg (abs) for sea water based once through CW system



- vi) *House- load Operation:* The TG set shall be capable of operating on House load using HP-LP bypass system during sudden total export load throw off. Unit shall not trip on overspeed in the event of total export load throw-off.
- vii) *No. of Start- ups:* Expected number of turbine generator start-ups during design life of minimum 25 years shall be as under. The design of turbine generator and the associated systems shall take care of these start ups without affecting the life of equipment adversely. No component shall be stressed beyond acceptable safe stress and fatigue levels when operating under the stated duty conditions.

a)	Cold Start (after shut down period exceeding 72 hours)	150
b)	Warm Start (after shut down period between 10 hours and 72 hours)	1000
c)	Hot Start (after shut down period less than 10 hours)	4000

12.1.5 Material requirements

The steam turbine shall be built-up using materials which are field proven.

12.1.6 Maintenance requirements

- i) *Wet Steam Washing (if applicable):* Necessary stubs/ connections on turbine/piping shall be provided for future connection to wet steam washing system, if applicable, as per standard practice of turbine manufacturer.
- ii) *Fast Cooling of Turbine:* Provision shall be made to facilitate fast cooling of turbine during emergency condition for quick access.
- iii) *Boroscopic Inspection:* Boroscopic Inspection ports shall be provided in turbine for in situ inspection of turbine internals as per standard practice. The inspection ports shall cover turbine internals as maximum as possible as per manufacturer Standard practice. The inspection port should be designed for ease of accessibility with leakage proof features while in operation.
- iv) *Preservation System:* Turbine preservation system shall be provided to protect against corrosion during idle periods as per OEM practice.

12.2 Turbine Casing

The turbine casing design shall have following features:

- i) Symmetrical in design to minimize effects of thermal stress and creep.



- ii) Steam tight horizontal joints with metal to metal contact or as per proven practice of the manufacturer.
- iii) All extractions shall preferably be from the lower half of casing and extraction branches shall be welded to casings except for LP casing(s) extractions which can be with either welded type or bolted type connection as per turbine manufacturer's standard practice.
- iv) Adequate drainage facility with temperature devices (in pair) shall be provided in casings, strainer- housings, stop and control valves, extraction lines etc. with provision for water detection and proper removal during start-up and shall be in accordance to ASME TDP-1.
- v) Pressure relief bursting diaphragm for LP casing(s) to limit the exhaust hood pressure within a safe margin from design pressure.
- vi) A completely self contained exhaust hood spray system shall be provided for LP casing(s) to protect the turbine against excessive temperature due to windage at no load / low load and HP/LP by pass operations.

12.3 Turbine Rotor

- 12.3.1 Rotor shall be of forged alloy steel.
- 12.3.2 Maximum permissible shaft vibration measured at bearing housing shall be as per zone A of ISO 7919 and maximum permissible bearing vibration measured at bearing housing will be as per zone A of ISO 10816-2.
- 12.3.3 Critical speed of composite rotor and blade assembly shall not be within (-)10 % to (+)15% of the operating speed.

12.4 Nozzles and Blades

- 12.4.1 Nozzles and blades shall be made from hard, corrosion & erosion resistant alloy steel.
- 12.4.2 LP blades design without lacing wires is preferred. The LP last stage blades shall be designed for effective removal of moisture.
- 12.4.3 Hardening of LP last stage blades upto 1/3rd (minimum) of blade length & width 25mm (minimum) or stellite or design of LP last stage blades with provision of moisture removal as per the proven standard practice of OEM shall be provided.
- 12.4.4 There shall be no resonance of LP blading in the continuous operating frequency range of 47.5 Hz to 51.5 Hz.



12.4.5 Independent tuning of free standing LP turbine blades shall be provided to avoid resonance frequency in the operating frequency range of 47.5 Hz to 51.5 Hz.

12.5 Bearings

Adequate number of Journal and thrust Bearings shall be provided with following features:

- i) Tin base babbit lining properly secured to the bearing shell.
- ii) Pressure lubrication.
- iii) Independent supporting arrangement out side the turbine casings and easy access.
- iv) Horizontally split with the ability to dismantle and replace lower half with minimum shaft lift.
- v) Provision for measuring bearing temperature as near the point of heat generation as possible and for measuring the oil temperature leaving the bearing.
- vi) Local temperature indicators in each bearing lube oil drains; embedded redundant duplex resistance elements/ thermocouples for monitoring temperature of bearing; necessary pick-ups and accessories for remote monitoring of bearing metal temperature & vibrations (Horizontal & Vertical).

12.6 Turning Gear

12.6.1 Suitable turning gear device, either high-speed hydraulic type or motorized type shall be provided as per standard proven practice of the manufacturer.

12.6.2 Automatic engagement/ disengagement of turning gear shall be ensured with shaft speed decrease/increase at preset value.

12.6.3 Manual hand barring facility shall also be provided for manually cranking the turbine incase of emergency including A-C power failure. Availability of lube oil to the bearings shall be ensured during manual barring operation.

12.6.4 The turning gear shall be provided with instrumentation & control for remote operation from unit control room.

12.7 Gland Sealing System (steam turbine and TD-BFP drive)

12.7.1 Gland sealing system for the TG set and BFP drive turbine shall comprise of spring back/ without spring back Labyrinth seal and turbine shaft glands sealed with steam.



12.7.2 Fully automatic gland sealing steam supply system shall be provided. Gland steam condenser, designed to operate under vacuum, shall be provided to condense and return to cycle all gland leak off steam along with 2x100% capacity exhausters (AC motor drive) to remove air and non condensable gases. Arrangement for bypass of gland steam condenser on condensate side shall be provided, if applicable, as per standard practice of the turbine manufacturer.

12.7.3 The turbine shall be self-sealing during normal operation. During start up and low load operation, sealing steam shall be supplied from alternate source of steam i.e. aux. steam header, along with a facility to automatically switchover from alternative source to the main source and vice-versa. During changeover of steam supply source from turbine/auxiliary steam header, there shall be no rubbing at glands and no undue increase in vibration and the system shall be capable of withstanding thermal shock.

12.7.4 The gland sealing arrangement for steam turbine shall permit easy examination and replacement of glands without lifting the upper half of turbine casing.

12.8 Steam Admission Valves (emergency stop, reheat stop, interceptor stop valves and control valves)

12.8.1 The steam turbine shall be provided with main steam emergency stop and control valves and reheat steam stop valves and interceptor valves.

12.8.2 Valves shall be hydraulically operated, fail safe type & equipped with test device to permit complete closing of one valve at a time while the unit is carrying load.

12.8.3 Valves shall close simultaneously & automatically when the over-speed governor trips and upon the action of other protective devices.

12.8.4 Steam admission valves shall be close to the turbine casing for limiting turbine over speeding to safe limits because of entrapped steam volumes.

12.8.5 The valves shall be designed to allow blowing out of steam leads prior to startup and avoid seizure under operating condition. Alternatively, chemical cleaning process shall also be acceptable as per standard practice of OEM.

12.8.6 The valves shall withstand high erosion by stellite or other superior methods as per standard proven practice of the manufacturer and shall be free from vibrations at high steam velocities.

12.9 Non- Return Valves (NRVs)

12.9.1 Hydraulic/ pneumatic power operated/ assisted quick closing type NRV (QCNRV) and ordinary NRV of proven design shall be provided for each



steam extraction line (except for extractions from LP turbine) including steam extraction line to BFP drive turbine. For extractions from LP turbine (except for heaters in condenser neck) and for each CRH line, one hydraulic/ pneumatic power operated/ assisted QCNRV shall be provided.

12.9.2 NRVs shall be suitable for on load testing individually and shall be provided with fail safe design and shall close on loss of power and during turbine trip.

12.9.3 The NRVs shall meet the requirements of turbine protection as per ASME TDP-1 and shall be located as close to the turbine as possible so as to reduce quantity of entrapped steam.

12.9.4 The material of the NRV's shall be compatible to the material of piping on which they are mounted. However, it shall not be inferior to the following:

i)	NRVs on CRH line & extraction lines to HP heaters	Alloy steel (WC9) or equivalent compatible with the connected piping
ii)	Other NRVs	Carbon steel (WCB) or equivalent compatible with the connected piping

12.10 Insulation (steam turbine and BFP drive turbine)

12.10.1 Insulation & cladding shall be provided for all equipment and piping with surface temp more than 60⁰C. Temperature of cold face of finished insulation shall not exceed 60⁰C with ambient temperature of 40⁰C. The wind velocity for insulation thickness calculation shall be considered as 0.25 m/s.

12.10.2 The insulation and cladding shall comply with requirements indicated in Chapter- 18 of this document.

12.10.3 Asbestos in any form shall not be used for insulation and for any other purpose.

12.11 Turbine Governing System

The steam turbine generator shall be equipped with an electro-hydraulic governing system with mechanical-hydraulic back up or electro-hydraulic system with 100% hot back-up as per standard and proven practice of OEM and shall meet the following requirements:

i) The governing system shall be capable of controlling with stability the turbine speed between zero to maximum power output when the unit is operating isolated or in parallel with other units.

ii) Over speed during full load loss shall be limited without triggering overspeed protection.



- iii) Adjustable steady state speed regulation shall be provided between 3% to 8% of rated speed.
- iv) Dead band at rated speed and at any power output within rated output shall not exceed 0.06% of rated speed.

12.12 Turbine Protective Devices

12.12.1 Emergency governor

- i) A separately actuated over speed device called emergency governor shall be provided to trip the Unit at about 110% of rated speed in case speed governor fails to limit the turbine overspeed.
- ii) The emergency governor resetting shall be as per manufacturer's standard practice. However, it shall meet the IEC-45 requirements for overspeed trip.
- iii) Means for testing the operation of emergency governor shall be provided to test operation when the machine is on load without exceeding the rated speed of the unit.

12.12.2 Emergency hand trip device

Turbine shall be provided with an emergency hand trip device to facilitate manual tripping of the unit from local along-with facility to trip turbine from unit control room.

12.12.3 Other protective devices

Other turbine protection devices including vacuum trip device, thrust bearing trip device shall be provided as per standard practices of the manufacturer.

12.13 Unloading Devices

12.13.1 Low vacuum unloading device

A low vacuum unloading device shall be provided (if applicable, based on standard proven practice of the OEM for the unit size in consideration), which shall ensure progressive decrease of steam flow to turbine below a preset value of condenser vacuum, thus restoring the condenser vacuum.

12.13.2 Vacuum breaker

A D.C. operated device shall be provided for rapid reduction of vacuum in condenser for turbine rotor to be brought to rest as quickly as possible.



12.14 Turbine Lubrication Oil System

A self contained lubrication oil system shall be provided for each TG Unit consisting of:

- i) Centrifugal/ gear type, main oil pump (MOP) directly driven by turbine shaft or by an AC motor as per manufacturer's standard practice with capacity to cater lube oil for bearings & emergency seal oil requirement. In addition to above, minimum 1x100% AC Aux. oil pump shall be provided for start up, shut down of TG unit and as standby to MOP for automatic operation catering for requirement of lubricating oil, jacking oil & turning gear oil.
- ii) One DC motor driven emergency oil pump with sufficient capacity for meeting lubricating oil requirement of bearings during emergency.
- iii) 1x100% capacity each AC & DC jacking oil pumps.
- iv) Unit lube oil tank of SS with capacity to allow 5 to 8 oil changes per hour (at normal operating level), fitted with non-corrodable strainer and 2x100% duty vapour extraction fans driven by explosion proof motors.
- v) 2x100% DM water cooled lub oil coolers of tube & shell type designed as per TEMA or plate type designed as per relevant codes. The coolers shall be provided with 15% excess heat transfer surface area and with oil pressure greater than water pressure.
- vi) Piping and all other components of the system coming in contact with oil shall be of stainless steel.

12.15 Turbine Lubricating Oil Purification System

Each T.G. unit shall be provided with a permanently connected, continuous oil purification system comprising of following major equipment:

- i) Oil purification system shall be of either centrifuge type or coalescing type as per proven standard design of OEM and shall have the capacity to purify 20% of total oil charge in system per hour. The purified oil shall have maximum particle size conforming to code 15/12 as per ISO 4406 and moisture content not more than 500 ppm or as per requirement of the turbine manufacturer which ever is more stringent. The above purity shall be achievable with particle size and moisture content of inlet oil conforming to code 21/18 as per ISO 4406 and 15000 ppm respectively in one pass.
- ii) Carbon steel anti-flood tank, applicable for centrifuge type purifier.
- iii) Positive displacement feed & discharge pumps (if required), each having capacity 10% higher than purifying unit.



- iv) Electric oil heater to heat oil to temperature not more than 65°C with possibility to cut heater elements in steps, applicable for centrifuge type purifier.
- v) Duplex type filters/strainers with stainless steel element of size 5 micron or a size suited to the requirement of the turbine.

12.16 Turbine Control Fluid System

Turbine control fluid shall be supplied either from turbine lubricating oil system or from a separate control fluid system as per standard practice of the OEM. In case of separate control fluid system, each unit shall be provided with the following:

- i) Fire resistant fluid for control fluid system for servo motors of all hydraulically operated turbine stop and control valves, hydraulically operated extraction NRVs and spray water valves for LP bypass system.
- ii) 2x100% AC driven pumps connected to fluid reservoir along with hydraulic accumulators.
- iii) Fluid reservoir of adequate capacity fitted with non-corrodable strainers and 2x100% vapour extraction fans (if required as per type of control fluid used).
- iv) 2x100% control fluid coolers (water or air cooled) as per standard practice of manufacturer.
- v) Control fluid purifying unit with capacity to purify at least 2% of the total fluid charge in the system per hour on a continuous/ intermittent bypass basis alongwith 2x100% capacity A.C. driven purification pumps (for fluid circulation through purification system).
- vi) Duplex oil filters at downstream of all pumps with mesh size as per OEM's standard and practice.
- vii) Tank, Piping and all other components of the system coming in contact with control fluid shall be of stainless steel.

12.17 Central Turbine Lubricating Oil Storage and Purification System

A central turbine lubricating oil storage and purification system shall be provided for the plant. The system shall consist of identical clean and dirty oil tanks each with capacity 1.5 times the capacity of one unit oil tank, purification system identical to unit purification system and 2x100% capacity oil transfer pumps with provision to add new oil to any unit oil tank.



CHAPTER - 13

STEAM CONDENSING PLANT

13.1 General Requirements

- 13.1.1 Design, manufacturing and testing of condensing plant shall be as per Heat Exchange Institute, USA (latest). For performance testing of condenser and pumps, ASME PTC codes shall be used. The thermal, hydraulic and mechanical design shall be proven.
- 13.1.2 The steam condensing plant shall be suitable for specified condenser cooling water system and materials of construction of various components/equipments shall be suitable for intended service.
- 13.1.3 Isolating butterfly valves and expansion bellows shall be provided at inlets and outlets of condenser cooling water on each half of condensers. For dual pressure condenser, isolating valves may not be required at LP shell outlet and HP shell inlet.
- 13.1.4 Condenser shall be designed for installation of LP heater(s) in condenser neck. Extraction pipes routed through condenser neck shall be provided with stainless steel shroud to prevent erosion due to steam.
- 13.1.5 Separate sponge ball type condenser on-load tube cleaning system for each half of condenser including ball circulation pumps, strainer and ball monitoring system, shall be provided.
- 13.1.6 Maximum oxygen content of condensate leaving the condenser shall be 0.015 CC per litre over the entire load range except during start up and low load conditions.
- 13.1.7 For normal make up to the power cycle, DM water shall be added in the condenser from DM storage tanks/ condensate storage tank (CST) through a control valve. The emergency make up to the condenser(s) of each unit shall be supplied by 2x100 % centrifugal pumps of adequate capacity taking suction from CST.
- 13.1.8 The DM water to CST of each unit shall be supplied from DM water storage tanks of DM plant by 2x100% capacity pumps. The CST shall also receive excess flow of condensate from discharge of condensate extraction pumps. The condensate storage tank shall be of mild steel to IS 2062 Gr- B or equivalent with inside surface rubber lined to 4.5 mm thickness or epoxy coated. The effective storage capacity of each tank shall be 500m³.



13.2 Condenser

13.2.1 Construction

- i) Condenser shall be horizontal surface type of proven design with integral air cooling section and divided water-box construction.
- ii) Shell shall be of carbon steel as per ASTM SA285 Gr. C/ IS2062 Gr.B or equivalent and shall be suitable for intended service with welded construction and 16mm minimum wall thickness. The hot well shall be of same material as the shell, and shall be longitudinally divided with proper drainage provision.
- iii) Condenser shall be spring supported or solid supported as per standard and proven practice of the OEM.
- iv) Condenser shall be provided with easily removable/hinged type and refittable type water boxes along with suitable handling arrangement for the same. Hinged manhole (of minimum 460 mm size) shall be provided in shell, each water box and each hotwell section.
- v) For fresh water based application, tubes shall be of welded type stainless steel as per ASTM A-249-TP304⁴ and meeting the ASME specification for general requirements for carbon ferritic alloy and austenitic alloy steel tubes SA-450 and continuous without any circumferential joint suitable for the duty intended, with minimum tube size (OD) as 22.225 mm and nominal wall thickness of minimum 22 BWG.
- vi) Water box & support plates material shall be of carbon steel as per ASTM A285 Gr. C/ IS2062 Gr. B or equivalent and tube plate shall be of carbon steel as per ASTM A285 Gr. C.
- vii) Corrosion allowance of minimum 1.6 mm shall be provided for water boxes, tube plates, shell, hotwell and condenser neck. Corrosion allowance shall not be required for SS tube plates.
- viii) Water box interiors shall be painted with two coats of corrosion resistant primer and coated with coal tar epoxy paint or shall be rubber lined as per duty requirements involved. Tube plate on water side may alternatively be provided with suitable cladding as per standard practice of OEM.
- ix) Condenser design shall provide for efficient steam distribution in the condenser when one half of condenser is isolated and shall ensure at least 60% of rated output under this condition.

⁴ For sea water application, the tubes shall be of titanium B- 338 Gr- II and continuous without any circumferential joint with average wall thickness of minimum 22 BWG.



- x) Suitable provisions shall be made for expansion between shell and tubes. Further, suitable provisions (like sliding and fixed base plate of condenser support feet etc.) shall also be made for expansion of condenser shell under various operating conditions.
- xi) Air release valves and vacuum priming pumps (if applicable) shall be provided in water box of the condenser.

13.2.2 Design requirements

- i) The Condenser shall be designed for heat load corresponding to unit operation for valves wide open (VWO) condition, 0% make up and design condenser pressure and other conditions given below. Condensate temperature at all loads shall be near to saturation temperature corresponding to condenser pressure.
- ii) The Condenser hotwell shall be sized for three (3) minute storage capacity (between normal & low-low level) of total design flow with the turbine operating at VWO condition, 0% make-up, design condenser pressure. The low-low level of hotwell shall be at least 200 mm above the bottom of hotwell.
- iii) Steam dumping device shall be sized to accept the steam from LP bypass with necessary spray water and abnormal conditions like HP heaters out of service etc.
- iv) Air removal section shall be designed to cool the air and vapour mixture to at least 4.17 deg. C below saturation temperature corresponding to 25.4 mm Hg (abs). Connections to air evacuation pumps shall be made at this section.
- v) The condenser shall be designed to accept exhaust steam from steam turbine, BFP drive turbine, HP-LP bypass system, heater drains and vents, boiler separator drains during start up, low load and abnormal conditions like HP heaters out of service and other miscellaneous drains.
- vi) The condenser shall be designed to carry flooded weight (upto 1 meter above top row of condenser tubes) for hydraulic and hydrostatic testing of condenser without installation of temporary supports or bracing.
- vii) C.W. butterfly valves with actuators shall be designed as per AWWA-C-504 or approved equivalent standards.
- viii) C.W. expansion joints shall be made from high quality natural/synthetic rubber with carbon steel reinforcement rings and with flanges as per Class D of AWWA C 207. The expansion joints shall be designed as per expected deflections and fluid pressure during all plant operating conditions and shall be suitable to withstand full vacuum without collapse.



13.2.3 Design parameters for condenser and associated systems

i)	<i>Condenser Design Parameters</i>	
	a) Number of pressure stages	Single pressure/ dual pressure
	b) Number of passes	Single pass/ double pass
	c) Number of shells	One/ two
	d) Design cold water temp	33 ⁰ C ⁵
	e) Water velocity in the tubes	1.6 to 2.2 m/s
	f) Maximum design condenser pressure	77 mm Hg (abs) ⁶
	g) Max. tube length between tube plates	15 m (indicative)
	h) Temperature rise of circulating water across the condenser	9 to 11 deg C ⁷
	i) Cleanliness factor	0.9
	j) Fouling factors	As per HEI
	k) Tube plug margin	5% under design condition
	l) Max. CW side pressure drop across condenser and associated piping system at design flow with tube cleaning system in operation	5 mwc for single pressure condenser & 9 mwc for dual pressure condenser
	m) Maximum/minimum temperature of circulating water	36 deg C ⁸ /15 deg C
	n) Condenser arrangement	Perpendicular to TG axis
	o) Water box design pressure	5.0 kg/cm ² (g) and 0.1 kg/cm ² (abs)
	p) Water box test pressure	1.3 times the design pressure (minimum)
	q) Water box design temperature	60 ⁰ C
	r) Shell side design pressure	Full vacuum and 1.08 kg/cm ² (g)
	s) Shell side design temperature	120 ⁰ C
ii)	<i>Design Parameters for Isolating Butterfly Valves, Expansion Joints and CW Piping etc.</i>	
	a) Design pressure	5 kg/ cm ² (g) and 0.1 kg/cm ² (abs)
	b) Design temperature	60 ⁰ C
	c) Test pressure	1.3 times the design pressure (minimum)

⁵ 30⁰⁰C for sea water based once- through type CW system

⁶ 60mm Hg (abs) for sea water based once- through type CW system

⁷ Not to exceed 7⁰C for sea water based once- through type CW system

⁸ 33⁰C for sea water based once- through type CW system



iii)	<i>Condenser Air Evacuation System Design Parameters</i>	
a)	Source of vacuum pump heat exchanger cooling water	Condenser cooling water
b)	Source of sealing water	Condensate
c)	Source of make-up water	Condensate
d)	Design pressure (cooling water side) for vacuum pump heat exchanger	Vacuum (0.1 kg/ cm ² (abs)) and as per ACW system design pressure
e)	Maximum temperature of condenser cooling water	36 ⁰ C ⁹
f)	Duty code	HEI
g)	Design back pressure	25.4 mm (1 inch) of Hg (abs)

13.3 Condenser Air Evacuation Pumps

13.3.1 Two nos. (2x100%) air evacuation pumps along with all accessories and instrumentation shall be provided for each condenser/ shell. Alternatively, 3x50% air evacuation pumps shall also be acceptable in case of two shell condenser/ dual pressure condenser as per standard and proven practice of the OEM.

13.3.2 Pumps may be single/two stage liquid ring type with both stages (if two stage pumps provided) mounted on a common shaft.

13.3.3 Pumps shall be suitable for indoor installation and for continuous duty. Each pump and its accessories shall be mounted on common steel base plate. Pump shall be connected to motor by flexible coupling.

13.3.4 Sizing of pumps shall be as per HEI (latest).

13.3.5 Total evacuation capacity of working pump(s) in free dry air at standard condition with condenser operating at design pressure of 1 inch (25.4 mm) of Hg (abs) and sub cooled to 4.17⁰C below temperature corresponding to absolute suction pressure shall be minimum 36 scfm in case of one shell condenser for 660 MW unit and 48 scfm in case of two shell condenser for 660/ 880 MW unit under standard conditions i.e. 760mm Hg (abs) and 21.1⁰C.

13.3.6 Flexibility shall be provided for operating all the vacuum pumps during hogging and must be able to evacuate the condenser(s) in specified time as per HEI. Capacity of each pump during hogging operation shall as per criterion given in latest version of HEI plus 20% margin.

13.3.7 Selection of materials for vacuum pumps and seal water recirculation pumps shall be as below:

- i) Casing - Nickel cast iron

⁹ 33⁰C for sea water based once- through system.



- ii) Shaft - Carbon Steel (EN8)
- iii) Impeller - Nodular iron/stainless steel
- iv) Shaft sleeves-Nodular iron/stainless steel

13.3.8 The stand-by pump shall cut in automatically in case running pump fails or when condenser pressure falls back to a preset value.

13.3.9 Vibration levels for the pumps shall be as per “zone A” of ISO 10816.

13.4 Condenser On- Load Tube Cleaning System

13.4.1 Sponge rubber ball type tube cleaning system designed for continuous & trouble free operation shall be provided. The system shall have provision of abrasive coated balls cleaning in case of hard deposits inside tubes.

13.4.2 Suitably sized non clog type ball recirculation pump shall be provided along with suitable ball injection nozzles to inject the cleaning balls into respective CW inlet pipe.

13.4.3 Suitable ball collecting strainer shall be provided at CW discharge pipe to collect the cleaning ball and the same will be drawn off to the suction of ball recirculation pump.

13.4.4 Sufficient capacity ball collecting vessel shall be provided to hold the full charge of balls. Automatic / manual ball sorter shall be provided to sort out under size balls.

13.4.5 Provision shall be made to avoid any dead zone inside the water box. There shall not be crowding of balls at inlet of ball collecting strainer at discharge pipe. Further, provision shall be made to prevent loss of balls under normal and abnormal operating conditions including tripping of CW pumps.

13.4.6 The system should be complete with necessary instruments, protection and interlocks, along with manual and automatic back washing system and ball monitoring system consisting of separate ball circulation monitor and ball oversize monitor.

13.5 Condensate Extraction Pumps (CEP)

i)	Configuration	3 x 50 % CEPs per unit.
ii)	Drive	Constant speed squirrel cage induction motor with speed of 1500/ 1000 rpm (synchronous).
iii)	Constructional Requirements	Vertical, multistage, cannister type, centrifugal, diffuser type with double suction first stage impeller.



iv)	Shaft sealing	Either mechanical seals or packed type with external water sealing designed to prevent air ingress to condenser even when the pump under shut down and exposed to condenser.
v)	Impeller/Casing design	Closed and nonover-loading type impeller with wear rings on pump bowls.
vi)	Materials	a) Suction bell/pump casing : Cast Iron. b) Impeller/ wear rings/ shaft/ shaft sleeves :12%Cr stainless steel. c) Cannister : Fabricated mild steel.
vii)	Pump Sizing	
	a) Design Capacity	Combined flow of 2 x 50 % CEP to be based on 10% margin over highest condensate flow envisaged during unit operation (excluding HP/ LP bypass operation).
	b) Design Head	The design head shall be worked out considering minimum 10% margin in piping friction for highest condensate flow as at (i) above and 10% margin over maximum deaerator pressure.
	c) Best efficiency point	Combined flow of 2x50% CEPs shall be based on TMCR requirement and corresponding head.
	d) Maximum Capacity	One pump shall be capable of handling the flow and head corresponding to 65% unit load.
	e) Other Capabilities	1. Two pumps shall be capable of handling the flow corresponding to Unit TMCR, all HP heaters out, 1% make up and worst condenser pressure at 47.5 Hz. 2. Two pumps shall be capable of handling the flow corresponding to HP - LP by pass operation with turbine under tripped condition as well as turbine on house load.
	f) NPSH Margin	NPSH (R) at 3% head drop shall not be more than half the NPSH(A) at design flow with low low hotwell level and NPSH(R) at 3% head break shall be well below NPSH(A) under all conditions.



	g) Minimum recirculation	Minimum recirculation flow requirements of the pump shall be not less than 25% of design flow or on set recirculation (discharge/ suction) whichever is higher. CEPs can be provided with individual recirculation line or a combined recirculation line to cater to maximum of the pumps minimum flow and GSC minimum flow as per standard proven practice of OEM.
	h) Performance curve	Characteristic curve of pumps should be continuously rising type with decrease in flow and shut off head shall be between 115% to 130% of TDH at design point.
	i) Critical speed	First stage critical speed in water shall not be within 20% of pump design speed.
	j) First stage impeller life	Wear life due to cavitation of first stage Impeller shall not less than 40,000 running hours.
	k) Peripheral speed and suction specific speed	<ol style="list-style-type: none"> 1. The limiting peripheral speed shall be as per standard and proven practice of the manufacturer. 2. Suction specific speed of first stage impeller shall generally not exceed 11,000 U.S. units based on 3% head break of that impeller at design point.
viii)	Applicable codes	HIS- latest edition (for design) and ASME PTC 8.2 (for performance test).

13.6 Strainers at Suction of Condensate Extraction Pumps

- 13.6.1 Strainers shall be provided at suction line of each pump. Strainers shall be constructed of 16 gauge perforated stainless steel plates (SS304) and shall be lined with SS316 screen.
- 13.6.2 The clear area of the strainer shall be atleast 5 times the inlet cross-sectional area of the connecting pipe.
- 13.6.3 The pressure drop of the strainer at design flow under clean condition and 50% clogged condition shall not exceed 0.1 kg/cm² and 0.15 kg/cm² respectively.



13.7 Drip Pumps (if applicable)

- 13.7.1 In case drip pumps are envisaged for cycle optimization for forward cascading of LP heater drain, then 1x100% or 2x100% Drip pumps as per proven practice of the OEM shall be provided for each unit at any one location. The drip pump flow shall be based on 10% margin over highest drip flow envisaged during unit operation and design head shall be worked out considering minimum 10% margin in piping friction and 10% margin over maximum deaerator pressure.
- 13.7.2 The first critical speed of drip pump in water shall not be within 20% of design speed. Life due to cavitation of first stage impeller shall not less than 40,000 running hours.
- 13.7.3 Design pressure for bowls and discharge components shall correspond to shut off head at 51.5 Hz and operating specific gravity and maximum suction condition. The suction components shall be designed for 8 kg/cm² pressure and full vacuum.

13.8 Debris Filters (as applicable for sea water based systems)

- 13.8.1 Two number debris filters shall be provided on the circulating water pipelines upstream of the condenser for online filtering of cooling water.
- 13.8.2 Each debris filter shall comprise of perforated stainless steel screen, butterfly valves, turbulence flap (if required), debris flushing valve, drain plug valve, motor actuators for the valves, differential pressure gauge and control and instrumentation etc.
- 13.8.3 The materials of construction of various components shall be of proven type as per quality of water to be handled by the debris filters. Inside surface of the debris filters shall be coated with anti-corrosive paint to ensure long life.
- 13.8.4 The filters shall be capable of removing solids, suspended matter and fibrous material up to 5 mm size.
- 13.8.5 The operation of the debris filters shall be of automatic type with facility provided for remote manual operation also.
- 13.8.6 The maximum allowable pressure drop under clean screen condition and 50% choked condition shall be limited to 0.5 mwc and 1.0 mwc respectively. The filter shall be designed for pressure of 5 kg/cm² (g) and vacuum of 0.1kg/cm² (abs).



CHAPTER 14

FEED WATER HEATING PLANT AND FLASH TANKS

14.1 General Requirements

14.1.1 The plant shall be designed as per IS 2825 or ASME Boiler and pressure vessel code, section VIII, Division-I (Latest) and Heat Exchange Institute Standards (USA). In addition the requirements of latest edition of ASME-TDP-1 code for turbine damage prevention shall also be taken care of. Plant shall be designed for all operating conditions including transients like sudden load throw-off, HP-LP bypass coming in operation, preceding one or two heaters going out of service etc.

14.1.2 The HP heater drains shall normally be cascaded to successively lower pressure HP heaters and lowest pressure HP heater drain shall be led to the deaerator. The LP heater drains shall be cascaded to successively lower LP heaters and lowest LP heater drain shall be led to the condenser. Alternative HP heater drains shall be directly led to deaerator and condenser and alternative LP heater drains shall be directly led to condenser in case of increasing level in the heaters. The drains to the condenser shall be led through flash tanks.

14.1.3 The plant shall be suitable for operation in conjunction with steam turbine offered. It shall be capable of raising the temperature of feed water from that in the condenser to design temperature at the outlet of top heater at rated output with zero percent make-up and design back pressure. TTDs and DCAs of heaters shall correspond to the heat rate guarantee conditions.

14.1.4 The Feed regulating station (FRS) shall be located at upstream of HP heaters with no isolating valve provided at upstream of economiser. Each heater shall be designed for removal from service individually without shutdown of unit, using hydraulically operated or motorised bypass & isolating valves or fail safe type media operated three-way valve as per proven standard practice of OEM and as per approval of IBR. In case HP heaters are provided in two strings, these shall be isolated as a string and not individually.

In case HP heaters are provided with isolating & bypass valves, spring loaded relief valve(s) shall be provided in the bypass of each HP heater(s) so as to prevent BFP shut off pressure from being communicated to downstream piping system and HP heaters. Further, in case HP heaters are provided in two strings, 2x50% capacity spring loaded relief valves shall be provided in the bypass of HP heaters with each valve capable of bypassing 50% BMCR feed flow.

14.1.5 Heaters shall be designed with minimum pressure drop on tube side. Velocity of water through the tubes shall be restricted to 3.05 m/sec under normal operating conditions.



- 14.1.6 Each of the HP heaters, LP heaters and drain cooler shall be capable of handling 110% of the design flows from BFPs, CEPs as the case may be without undue vibrations and deleterious effects.
- 14.1.7 Heaters shall be provided with start-up and operating vents with orifices and relief valves. Provision shall be made for removing non condensable gases collecting on shell side individually to the condenser. Vent orifices shall be sized to pass 0.5% of rated steam flow to respective heater under TMCR conditions.
- 14.1.8 Tube material shall be stainless steel as per ASTM A 213 Gr TP304 for seamless tubes without circumferential joints, or ASTM A 688 Gr. TP304 for welded tubes.
- 14.1.9 Tube sheet material shall be carbon steel as per ASTM. A516 Grade 70 or SA 266 Gr- 2 or SA 350 LF-2 and it shall be welded to shell and water box. Tube support plates shall be of common quality steel of 16mm (min) thickness.
- 14.1.10 Tube size shall be minimum 15.875 mm OD and minimum wall thickness shall be as per HEI.
- 14.1.11 Corrosion allowance of minimum 3.2mm shall be considered for shell and water box of each heater.
- 14.1.12 Sentinel relief valve shall be provided on tube side. Relief valve on shell side shall be sized to pass flow from clean rupture of one tube (two open ends) or 10% of water flow corresponding to VWO condition with 1% make up and design condenser pressure at 10% accumulation whichever is higher and set to open at heater shell design pressure.
- 14.1.13 Arrangement shall be provided for preservation by nitrogen blanketing during shut down period.
- 14.1.14 Proper drainage of bled steam lines shall be ensured. Each bled steam line shall have ordinary and power assisted NRVs and motorized isolation valves except for heater mounted in condenser neck and extraction to heater from CRH line.
- 14.1.15 No copper or brass shall be used in the internal construction of heaters to avoid copper pick up through condensate/ drips.
- 14.1.16 Provision shall be made for differential expansion between shell and tubes.

14.2 Low Pressure Heaters and Drain Cooler

- 14.2.1 The LP heaters shall be horizontal and U-tube type with integral drain cooler. However, heater(s) in condenser neck may be of U- tube or straight type and may or may not be provided with drain cooler as per standard practice of the OEM.



- 14.2.2 Shell shall be of rolled steel as per ASTM A-516 Gr. 70. Water box channel shall be of carbon steel as per ASTM A-516 Gr. 70 and welded to tube sheet.
- 14.2.3 Design pressure: Tube side - CEP shut off head at 51.5 Hz and full vacuum; Shell side - Not less than maximum extraction steam pressure with minimum design pressure of 3 kg/cm² (g) and full vacuum.

14.3 Deaerator

- 14.3.1 Deaerator shall be spray-cum-tray with integral direct contact vent condenser mounted on horizontal storage tank, OR spray type with minimum two (2) spray control valves of disc type or equivalent, in order to ensure fine atomization of incoming condensate and rapid heating up by the steam.
- 14.3.2 Design and construction of deaerator shall be as per Indian Boiler Regulations, IS 2825 or ASME pressure vessel code for unfired pressure vessels, Section-VIII or any other equivalent code.
- 14.3.3 Anti-vortex arrangement shall be provided at discharge connections from deaerator.
- 14.3.4 All pressure parts like shell, heads and nozzles shall be of carbon steel as per ASTM A-516 Gr. 70. Shell shall be in welded construction with minimum plate thickness 15.8 mm. Corrosion allowance of minimum 3.2 mm shall be considered for the shell and dished ends.
- 14.3.5 Hardened 400 series stainless steel impingement plates shall be provided for flashed drain inlet from HP heaters, BFP recirculation, boiler startup drains etc.
- 14.3.6 All water spray valves, splash plates, trays, vent condenser and other elements in contact with undeaerated water or non-condensable gases shall be of stainless steel 304.
- 14.3.7 Deaerator safety valves of adequate relieving capacity made of 13% Cr. stainless steel disc and spindle shall be provided. Vent orifice shall be sized for capacity equal to 0.5% of rated flow to the deaerator.
- 14.3.8 Deaerator shall be designed for efficient steam distribution and de-aeration of condensate under all operating conditions including VWO with 1% make up, HP-LP bypass operation, HPHs out of service.
- 14.3.9 Deaerator shall be floating pressure type. Deaerator pressure shall vary with load when it gets steam from turbine extraction. Deaerator pressure shall be pegged at 3.5 kg/cm² during HP-LP bypass operation, major load rejection, turbine trip and low loads when extraction steam pressure is less than 3.5 kg/cm². During cold start-up, the deaerator pressure shall be maintained at



1.5 kg/cm² with steam from auxiliary steam header. During hot and warm startup, if boiler startup drain circulation pumps are in service, deaerator pressure shall be maintained at 3.5 kg/cm². In case startup drain circulation pumps are not in service and startup drains are routed through condenser, deaerator pressure shall be maintained 1.5 kg/cm². Steam supply shall be from auxiliary steam header. Alternatively, deaerator pegging pressure under different plant operating conditions may be decided by OEM as per his standard proven practice.

Design pressure & temperature shall not be less than extraction pressure or worst operating condition with sufficient margins above the same.

14.3.10 Sources for heating:

- i) Extraction steam from turbine IP-LP cross- over/ cross-around pipe or as optimized by OEM (normal operation).
- ii) Steam from CRH till extraction steam from normal source becomes available.
- iii) Steam from Auxiliary steam header till CRH steam becomes available.

14.3.11 Feed water storage tank capacity shall be based on minimum 6 (six) minutes of BMCR flow (approx.) between normal operating level and low-low level with a filling factor of 0.66. This capacity shall be exclusive of the volume of internal piping, baffles and volume of the dished end. It shall be designed for maximum incoming steam flow when none of the LP heaters are working under HP/LP bypass condition.

14.3.12 Designed to withstand full vacuum and pressure decay.

14.4 High Pressure Heaters

14.4.1 The HP heaters (1x100% or 2x50% strings) shall be of horizontal and U-tube type with desuperheating, condensing and drain cooling sections.

14.4.2 Heater shell shall be made of carbon steel as per ASTM-516 Gr. 70 and water box channel as per ASTM A-266 class-II and shall be welded to tube sheet.

14.4.3 *Tube Side Design Pressure:* With feed regulating station located at upstream of HPHs and no isolating valve provided at inlet of economiser, tube side design pressure shall be worked out corresponding to 105% of discharge pressure for emergency point of BFP operation as defined in clause 15.2. The HPHs shall be designed for full vacuum also.

14.4.4 *Shell Side Design Pressure:* Shell side design pressure shall not be less than maximum extraction steam pressure and full vacuum. For heaters taking



extraction from CRH line, the maximum expected HPT exhaust pressure shall also be taken into account.

14.5 Flash Tanks

14.5.1 The flash tanks shall be provided receive the drains and safety valve connections from various equipments and systems. These, as a minimum, shall include Unit flash tank, turbine drain flash tanks (left & right), HP drain flash tank and LP drain flash tank.

14.5.2 The drains shall be connected to the flash tanks via headers which shall be graded according to the pressure, the farthest from the tank being the drain connection with highest pressure. The arrangement for connection of various drains to the flash tanks shall be as under:

- i) The drains from MS piping and HP bypass piping including warm up line shall be connected to unit flash tank.
- ii) The turbine integral and power cycle drains shall be connected to turbine flash tanks with left side drains connected to left side flash tank and right side drains to the right side flash tank.
- iii) The drains from CRH, HRH, LP bypass piping including warm-up line, extractions to HP heaters, CRH and auxiliary steam to BFP turbine and deaerator (high pressure side) and drain, vent and safety valve connections on HP heaters shall be led to the HP flash tank. The drains of extractions to LP heaters, IP extractions to BFP turbine, BFP turbine integral system, CRH to BFP turbine and deaerator (low pressure side), auxiliary steam header, drain, vent and safety valve connections of LP heaters and drain coolers, deaerator overflow and CEP discharge vent shall be led to the LP flash tank.

The alternative scheme/ arrangement for connection of drains to different flash tanks as per standard proven practice of OEM shall be acceptable.

14.5.3 Flash tanks shall be designed as per the requirement of ASME boiler and pressure vessels (B&PV) codes, and ANSI standard. The design pressure and temperature for the pressure vessels (except bellows) to be designed shall be 3.5 kg/cm² and 215⁰C respectively. Flash tanks shall also be designed for full vacuum condition.

14.5.4 Corrosion allowance of 3 mm shall be added to the design thickness of the shell and head of the vessels. The minimum thickness of the vessels including corrosion allowance shall not be less than 8 mm.

14.5.5 The Shell, head, wear plate/ baffles shall be made of ASTM 285 Gr. C or equivalent material. The material of nozzle neck shall be ASTM A 106 Gr. B or equivalent.



- 14.5.6 The temperature in the flash tanks shall be maintained by using condensate spray or service water spray (for flash tanks open to atmosphere). The spray shall be automatically controlled. However, for flash tanks open to atmosphere continuous spray through an orifice shall also be acceptable.
- 14.5.7 Facility shall be provided for remote manual operation of the drain valves from the control room. Motor operated drain valves shall be interlocked to open/ close as per the process requirements. Position indication of drain valves shall be provided in the control room.



CHAPTER - 15

BOILER FEED PUMPS

15.1 Number and Type

- 15.1.1 2x50% capacity turbine driven feed pumps shall be provided for each unit for normal working along with 1x50% capacity motor driven feed pump for start up purpose and to serve as standby. Alternatively, 3x50% MDBFPs shall also be acceptable.
- 15.1.2 The MD-BFP shall be driven by constant speed squirrel cage induction motor with hydraulic coupling between motor and main pump and booster pump at other end of motor. TD-BFP shall be driven by variable speed turbine drive with suitable coupling between turbine and main pump and booster pump at other end of turbine with a gear box for each TD-BFP. Booster pump of TD-BFP may, alternatively, be separately driven by an electric motor as per standard practice of the OEM.
- 15.1.3 Main pump shall be horizontal, centrifugal type, multistage, outer casing barrel type, cartridge design with end rotor removal. Booster pump shall be single stage, two bearing design and double suction impeller type. Overhung impeller is not acceptable.

15.2 Pump Sizing

Design Criteria		TDBFP	MDBFP
i)	Design capacity & design head	<p>a) Combined flow of 2x50% Turbine driven Boiler feed pumps to be based on 10% margin over feed flow corresponding to turbine V.W.O. condition, 1% makeup, design condenser pressure and corresponding head.</p> <p>b) One TDBFP shall be capable of handling flow and head corresponding to 65% of rated unit load.</p>	<p>All conditions prescribed in column for TDBFP shall be required to be met by MDBFP, as applicable.</p> <p>The head developed by MDBFP shall be calculated in the same way as done for TDBFPs for all the conditions so that TDBFPs and MDBFPs can be operated in parallel.</p>



ii)	Best efficiency point	Combined flow of 2x50% TDBFPs shall be based on TMCR requirement and corresponding head.	
iii)	Emergency point	Two turbine driven feed pumps to be capable of generating the discharge pressure corresponding to steam generator highest safety valve set pressure at 100% BMCR flow.	Requirement of emergency point shall be met by MDBFP at 50 Hz grid frequency.
iv)	Other Capabilities	Combined flow of 2x50% TDBFP shall meet the following: a) BMCR flow and head corresponding to rated steam pressure. b) V.W.O. output, 1% makeup, worst condenser pressure (MDBFP should meet the corresponding requirement at 47.5Hz).	
v)	Rated discharge flow through interstage bleed off for reheater attemperation	As per 8% of maximum reheat steam flow for the unit as a minimum.	

Note: Discharge flow of main pump not to include any seal flow, warm-up flow and balance drum leakage flow.

15.3 Design Requirements

15.3.1 Pumps

- i) *NPSH Margin:* The ratio between NPSH (A) and NPSH (R) at 3% head drop for booster pump and main pump shall be not less than 2.5 at design point corresponding to lowest level of deaerator and maximum pressure drop across the suction strainer.
- ii) *Trip Speed of TD-BFP:* 10% above the design speed of the feed pump.
- iii) *Performance Curve:* The characteristic curves of booster pump and main pump should be continuously rising type with decrease in flow and shut off head shall be in the range of 115% to 130% of TDH at design point.
- iv) *Minimum Recirculation:* The minimum flow of the booster pump and main pump shall not be less than 25% of design flow. ON-OFF or modulating type minimum recirculation valve with valve body designed for about 40% of design flow shall be provided.



- v) *MD-BFP Lube Oil System:* Common lubricating oil system shall be provided for main BFP, booster pump, motor and hydraulic coupling with one shaft driven main oil pump, 1x100% capacity AC motor driven auxiliary oil pump, one (two in case of 3x50% MDBFPs) full capacity each of working oil cooler/ lube oil cooler, oil filters/ strainers and piping, valves, fittings, instruments etc. as required.
- vi) *Critical Speed:* The first critical speed in water above the speed corresponding to turbine overspeed trip condition and internal clearances being 150% of new clearance or 130% of design speed whichever is higher.
- vii) *First Stage Impeller Life:* Life due to wear due to cavitation of first stage impeller shall not be less than 40000 running hours.
- viii) *First Stage Suction Specific Speed:* The suction specific speed of first stage impeller for main pump and booster pump shall generally not exceed 8000 US units and 9500 US units respectively at their respective design point based on 3% head break down.
- ix) *Casing Design:* Casing shall be designed for pump shut off head corresponding to trip speed for TDBFP and maximum pump speed at 51.5 Hz for MDBFP under lowest operating density plus maximum suction pressure at booster pump.
- x) Brinell Hardness of casing wear rings shall be 50 points different from that of impeller wearing surfaces.
- xi) *Dry Running:* The pumps shall be capable of accepting complete loss of water due to incidents such as inadvertent complete closure of suction valve and brought down to rest in controlled manner from design condition with simultaneous closure of suction valve.
- xii) *TDH per Stage:* TDH per stage for the main pump shall not exceed 670 mwc at design point.
- xiii) *Materials*

a) *Main pumps*

1.	Barrel	Forged carbon steel with austenitic stainless steel inlay in high velocity zones and sealing surface.
2.	Inner casing, Impellers, stage pieces.	13% chromium steel casting.
3.	Wear rings, balancing drum bush	13% chromium steel with antigalling properties.



4.	Balancing drum	Stainless steel.
5.	Pump shaft	13% chromium steel forging.
6.	Shaft sleeves	High alloy chromium or chromium nickel alloy steel.

b) *Booster pumps*

1.	Casing	Cast steel.
2.	Impeller	13% chromium steel casting.
3.	Shaft, shaft sleeves and wearing rings	13% chromium steel forging.

- xiv) *MD-BFP Start-up Time:* Motor of MD-BFP shall be able to accelerate the pumps from standstill condition to rated pumping conditions in less than 15 seconds after receipt of starting signal while operating either singly or in parallel with other operating pump. The MDBFP and associated auxiliaries shall be designed for auto start up on failure of running equipment/ auxiliaries.
- xv) *Efficiency:* The efficiency of the BFP shall not be considered more than 83% (hot) for the purpose of arriving at capacity of the drive.
- xvi) *Applicable Code:* The pumps shall be designed as per latest edition of Hydraulic Institute Standards (HIS), USA.
- xvii) *Strainers:* The pumps shall be provided with suitable suction strainers.

15.4 Operational and Maintenance Requirements

- 15.4.1 Suitable warm up arrangement (if required) to start the pump rapidly shall be provided. However, pump should be capable of starting from any conditions without any warm up requirement in emergency.
- 15.4.2 Response and Performance characteristics of TDBFP and MDBFP shall be such that while operating in parallel the difference in flow handled by them and the flow proportionate to their rating corresponding to the load shall not be more than 5% of flow through any one pump.
- 15.4.3 Pressure lubrication (if necessary) of MDBFP shall be provided for emergency lubrication at the time of coasting down of the motor driven boiler feed pump set in the event of AC power failure.
- 15.4.4 In case of any possibility of the feed pump operating at flow beyond its maximum flow handling capability due to low system resistance, then necessary arrangements to protect the pump from such high flow condition shall be made without any necessity of reducing the plant load.



- 15.4.5 The inner pump element comprising shaft, impellers, stage casings shall be capable of being removed and replaced as a unit in not more than 15 hours without disturbing feed piping.

15.5 Mechanical Seals

- 15.5.1 Seals shall be of fully cartridge design. The Seal face materials shall not be inferior to rotating silicon Carbide and stationary Carbon seal face combination. The seal life shall not be less than 20,000 running hours between overhauls and seals shall have dry running withstand capability.
- 15.5.2 Each seal shall be provided with 2x100% magnetic filters, 2x100% tubular coolers, piping, valves, control & instrumentation etc. Further, in case of AC power failure, seal should be able to withstand without cooling water.

15.6 Hydraulic Coupling and Gear Boxes

- 15.6.1 The hydraulic coupling of MD-BFP shall be of combined gear box and fluid coupling type and shall be adequately rated to meet the requirement of pump characteristic over its entire operating range.
- 15.6.2 The hydraulic coupling shall be complete with stainless steel impellers, casing, self supported double duty roller bearings, pillow blocks and Kingsbury/ Mitchell thrust bearing or proven thrust bearing as per OEM's standard practice, oil sump, duplex oil filters to remove all particles upto 25 microns, oil temperature and pressure gauges, control pump for oil regulation if required, regulating valves, stainless steel scoop tube, lube oil/ working oil coolers as indicated under clause 15.3 (e), one portable type oil purifier of adequate capacity.
- 15.6.3 The gear boxes shall be of double helical type manufactured by hobbing process and shall be dynamically balanced. The gear casing shall be horizontally split and accurately machined to provide oil tight joints. Oil used shall be same as for the pump, motor and turbine and supplied from pump lubrication system.
- 15.6.4 Gear boxes shall be designed for continuous service with following service factors:
- i) TD-BFP (gear box between turbine drive and booster pump) : 2.0
 - ii) MD-BFP (combined gearing/hydraulic coupling) : 1.4
- 15.6.5 Design and manufacturing of gear boxes shall be as per AGMA 6011.



15.7 Drive Turbine

15.7.1 General

- i) The drive turbine shall be dual admission or single admission type with external/ integral control valve, single cylinder, condensing type.
- ii) Drive turbine of BFP shall get normal motive steam from IP-LP crossover/cross around pipe or from a point as per optimized cycle during operation of turbine from full load to 60% TMCR load or below, if possible.
- iii) During low unit load conditions, turbine bypass operation, shutdown operation when extraction pressure of the normal motive steam source is insufficient to operate the drive turbine, steam from alternate source, from the same unit, shall be admitted through a separate set of stop and control valves. Both sets of control valve shall be controlled by electro hydraulic governing system. Single admission turbine with an external control valve (to be operated from the governing system) can also be offered.

15.7.2 Design

- i) Design of drive turbines shall be generally in accordance with API 612 and 614 except as modified here in and proven practice of the manufacturer and also generally followed in thermal power plants and testing in accordance with ASME PTC-6
- ii) Turbine blades, in particular last stage blades to be independently tuned to keep the blade resonant frequencies away from operating speed. Also, last stage blading of turbine to be designed for protection against erosion/corrosion by moisture.
- iii) Turbine shall be designed for protection against water induction. All drains shall consist of motorised/ pneumatic drain valves with isolating valves (with fail open facility) and drain piping for connection to drain flash tank for warming up drains before and after valve seats i.e. casing drains, gland steam system drain, IP extraction CRH and auxiliary steam lines alongwith necessary controls.
- iv) Turbine shall be designed for electro hydraulic control system to control speed from 0% to 100%. It shall be of the type which provides continuous corrective action until equilibrium conditions are obtained in response to changes in external signals or speed change resulting from other causes, such as changes in energy of the steam available to a turbine during sudden load pick ups or rejection on the main turbine generator unit. The system shall ensure controlled accelerating of the drive turbine and shall prevent over speed without tripping of the equipment under any operating condition or in the event of maximum load rejection.



15.7.3 Casing

- i) The casing shall be designed to withstand the maximum pressure and temperature likely to be subjected during normal operation and 25% over rated pressure for short term duration.
- ii) Casing shall be horizontally split at the centre line for raising and lowering the upper halves and rotor to clear off remainder of machine.
- iii) Horizontal casing joint to be made tight with metal to metal contact. Gasket or grooves shall not be acceptable.

15.7.4 Drive turbine rotor

- i) Rotor shall be of forged steel, heat treated, accurately machined and proportioned in order to keep critical speed away from operating speed.
- ii) Turbine blading shall be designed to have a high efficiency of energy conversion, consistent with low loading, stressing and vibration consideration to ensure high degree of availability.
- iii) All nozzles and blading in steam path shall be of corrosion and erosion resisting alloy steel suitable for temperature encountered.
- iv) Rotor blading shall be securely fixed and readily renewable type. The blading shall be designed to minimize the blade end leakages.

15.7.5 Drive turbine stop and control valves

- i) Valves to be arranged to close through a trip device actuated either by over speed governor or by action of other protective devices
- ii) Control valves and their seats to have stellite inlays with their stem hardened. Alternatively, nitriding for seats and stems may be provided, if it is suitable for maximum encountered temperature. Stop valves to have provision for on load testing.
- iii) Valves shall be provided with removable internals to allow for seam blowing.
- iv) Stop valves shall be provided with removable stainless steel steam strainer for normal operation, and one extra strainer shall be provided for initial operation.



15.7.6 Bearings

- i) The bearing shall be designed to avoid oil whip. Bearings shall be spherically seated, horizontally divided type, with provision of adjustment and alignment of rotor, forced feed lubricated type, lined with babbit or suitable antifriction alloy.
- ii) Bearings to be arranged so that these are outside drive turbine for readily accessibility. Lower half of bearing to be capable of being removed and replaced by minimum lifting of shaft.

15.7.7 Turning gear

- i) The drive turbine shall be provided with an adequately sized AC motor driven or hydraulically operated turning gear for rotation of complete TDBFP train i.e. booster pump, gear box, drive turbine and main pump while unit being started or taken out of service. The turning gear shall have provision to automatically disengage when the turbine speed reaches beyond turning speed.
- ii) Hand barring gear shall be provided for manually rotating the drive turbine in an emergency. The lube oil shall be made available to the bearings during such operation.

15.7.8 Drive turbine lubricating oil system

- i) Each drive turbine shall be provided with a complete lubricating oil system which shall provide lube oil for drive turbine, main pump, booster pump and disconnect/ flexible coupling and also to cater the control oil of governing system and turning gear oil requirements. The lube oil system shall consist of:
 - a) 2x100% AC motor driven oil pumps.
 - b) 2x100% capacity oil coolers.
 - c) Oil reservoir with five minutes retention time.
 - d) An oil conditioning system of type and design as provided for main turbine oil system.
 - e) One DC motor driven emergency oil pump for bearings oil requirements only.
 - f) Duplex type full capacity oil filters of cartridge type with automatic bypass facility.
 - g) 2x100% AC motor driven oil vapour extractors.
 - h) One full capacity AC motor driven jacking oil pump (if required).
 - i) Other accessories to render the system complete.



- ii) Suitably sized hydraulic accumulators shall be provided in governing oil system to maintain system pressure, when there is a change over from one running pump to stand by oil pump. Also provision shall be made for initial air purging of the governor system.

15.7.9 Drive turbine exhaust

- i) The drive turbine exhaust shall be separately piped to the main condenser of the TG unit. Motorised butterfly valve shall be provided in each exhaust duct of BFP turbine for its isolation when not in use.
- ii) Alternatively separate condenser for the drive turbine may be provided. In such a case the size criteria for same shall be as applicable for the main condenser. Condenser air evacuation system and condenser on load tube cleaning system shall also be applicable for the condenser for BFP drive turbine. Also 2 x 100% condensate extraction pumps shall be provided for removal of condensate from condenser of BFP drive turbine to main condenser.



CHAPTER – 16

GENERATOR AND AUXILIARY SYSTEMS

16.1 Generator

The turbo-generator set with all auxiliary systems and accessories shall have following features/ parameters:

16.1.1 **Type** 3-phase, horizontal mounted, 2-pole cylindrical rotor type, directly driven by steam turbine running at rated speed conforming to the latest version of IEC-60034-1, 60034-3 or other equivalent international standards.

16.1.2 Rating

i) Rated Output 776MVA for 660 MW or
941 MVA for 800 MW

Generator and its excitation system shall have capability to at least match the declared maximum continuous rated output of the associated steam turbine (for the secondary cooling water temperature of 39⁰C) at all power factors between 0.85 lagging and 0.95 leading with +3% to -5% frequency variation, terminal voltage variation of +/-5% as per IEC-60034-3 and combined voltage & frequency variation of 5%. It shall be ensured that when the Generator is working at this capability and cooling water temperature is 39⁰C, no part of the Generator shall attain a temperature in excess of the temperature limits specified for Thermal Class 130(B) insulation as per IEC-60034.

Also the generator and its excitation system shall be capable of continuous stable operation without any excessive temperature rise at the peak output of the associated steam turbine under VWO and HP heaters out conditions, etc. as available for the secondary cooling water temperature of 39⁰C at all power factors between 0.85 lagging and 0.95 leading with +3% to -5% frequency variation, terminal voltage variation of +/-5% and combined voltage & frequency variation of 5%. Temperature of different parts may exceed those permissible for Thermal Class130(B)



insulation under such operating conditions, but shall be lower than those permissible for Thermal Class 155(F) insulation as per IEC-60034.

- | | |
|-------------------------|--------------------------------|
| ii) Power factor | 0.85 (lag) |
| iii) Terminal voltage | As per manufacturer's practice |
| iv) Frequency | 50 Hz |
| v) Speed | 3000 rpm |
| vi) Short circuit ratio | ≥ 0.48 |
| vii) Efficiency | $> 98\%$ |

16.1.3 System of cooling

- | | |
|--|---|
| i) Stator winding | Closed loop system using Hydrogen or using demineralised water flowing through the hollow conductors. |
| ii) Rotor winding | Directly cooled by hydrogen. Alternatively, manufacturer's standard and proven arrangement of rotor cooling with water shall also be acceptable. |
| iii) Stator core | Cooled by hydrogen flowing through the radial and/ or axial ventilating ducts or water cooled. |
| iv) Configuration for hydrogen cooling | Generator to be designed for hydrogen pressure as per manufacturer's practice. The shaft mounted fan(s)/ blower(s) to be provided on one or both sides to facilitate circulation of hydrogen inside the machine. Hydrogen to be cooled by coolers using demineralised water mounted on the stator body. |
| v) Capacity with reduced cooling | Capable of delivering at least two-third of the rated and maximum continuous MVA with ten (10) percent of tubes in each cooler plugged without exceeding the temperature limits of thermal class 130(B) and thermal class 155(F) respectively. |

16.1.4 Insulation

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|---------------------------|--------------|
| Stator and Rotor windings | Class 155(F) |
|---------------------------|--------------|

16.1.5 Operational requirements

Generator shall be capable of delivering rated output under following operational conditions:



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|---|--|
| i) Voltage variation | (±)5% of rated value at rated power and rated power factor (as per IEC-60034-3). |
| ii) Frequency variation | (-)5 to (+)3% of 50Hz at rated power and rated power factor (as per IEC-60034-3). |
| iii) Combined voltage and frequency variation | 5% (absolute sum). |
| iv) Power factor variation | 0.85 (lag) to 0.95 (lead). |
| v) Operation under unbalanced load | As specified in IEC 60034 -1. |
| vi) Operation under unsymmetrical short circuit | $I_2^2 t$ (where I_2 and t are negative sequence current in p.u. and time in seconds respectively) to be as per IEC 60034 – 1. |
| vii) Voltage waveform | Total harmonic distortion (THD) to be within limits specified in IEC-60034-1. |
| viii) Short circuit withstanding capacity | Capable of withstanding of 3-phase short circuit at the generator terminals when operating at rated MVA and power factor with 5% over voltage for a period of not less than 3 seconds. |
| ix) Special operating conditions | Capable of withstanding the electrical, mechanical and thermal stresses developed during fast reclosing of high voltage line, transmission line switching, out of step operation and out of phase synchronization etc. |
| x) Line charging capability (MVAR) | Not less than 30% of the rated MVA at zero power factor leading. |
| xi) Generator neutral earthing | Non-effectively earthed neutral system. Neutral to be earthed through a distribution transformer loaded with a resistor. The core design to permit the flow of earth fault current of at least 15A for 1 second without major any core damage. |
| xii) Impulse level and surge protection | Impulse level as per IEC-60034, Pt.15 or as mutually agreed between Manufacturer and the Purchaser.
Surge arrestor of suitable rating to be provided for the surge protection of the generator winding. The surge capacitors also to be included. |



16.1.6 Design and constructional features

All components of the generator to be designed to avoid resonance at any of the frequency in the operating range.

i) *Stator Body*

Enclosure To withstand without any residual deformation, any internal hydrogen explosion.

ii) *Stator Core*

Material High permeability, low loss, cold rolled silicon sheet steel segmental punchings.

iii) *Stator Winding*

a) Winding configuration Stator winding consisting of three phase, double layer, short chorded, bar type winding having two parallel paths or multiple parallel paths (for indirect hydrogen cooling), but in case of double star winding, the total number of terminal bushings shall be either six (6) or nine (9). The elementary conductors to be Roebel transposed in the slot portion.

b) Winding insulation Epoxy thermo-setting type and rated for class 155(F). Provided with adequate protection on the winding and slots for avoiding the corona and other surface discharges.

iv) *De-mineralized (DM) Water Headers (if applicable)*

a) Inlet and outlet water headers Shall be of stainless steel / SUS/ Copper.

b) Insulation The headers and header connections as per manufacturer's standard practice shall be acceptable and shall be suitably insulated from the stator body.

v) *Stator Winding Connection and Terminal Bushings*

a) Winding Star connected. 3 phase and 3 neutral terminals brought out. In case of double star winding, the total number of terminals shall be either six (6) or nine (9). All stator terminal lead connections inside the generator to be suitably supported to contain vibration.



- b) Winding overhang Overhang portion of winding to be braced and supported to withstand three phase short circuit at its terminal as per IEC-60034.
- c) Bushing housing To be housed in stator frame in a non-magnetic steel terminal box or as per proven manufacturer's practice.
- d) Bushing Porcelain/ epoxy based material with non-hygroscopic property with suitable cooling arrangement.
- vi) *Rotor* Machined from a single alloy steel forging to give the required mechanical, metallurgical and magnetic characteristics. Shall have an adequate margin between critical speed and the running speed to ensure smooth running.
- vii) *Rotor Winding*
 - a) Conductor Coils made of hard drawn silver bearing copper.
 - b) Insulation Epoxy glass based material rated for class 155(F) insulation.
 - c) Retaining rings Retaining ring of high strength, non-magnetic alloy steel forging of Mn18Cr18, resistant to stress corrosion to be provided to prevent the movement of rotor winding in the radial/ axial direction due to centrifugal/ thermal stresses.
 - d) Locking nuts/ snap rings High strength non-magnetic alloy steel forging to be provided on the retaining rings or as per manufacturer's proven arrangement of locking to prevent any axial movement.
 - e) Centering rings To be mounted at the end of the retaining rings to support it in position or applied as per manufacturer's standard practice.
- viii) *Bearings*
 - a) Type Self aligning type sleeve/ tilting pad type bearings either mounted on separate pedestals or on the end shields. Bearing housings and its shells to be of split construction. Shells to be lined with tin based babbitt metal.
 - b) Seal Provided with labyrinth shaft seals/ oil deflectors.



- c) Jacking arrangement (if required) The hydrostatic jacking arrangement in line with turbine bearings.
- d) Bearing insulation At least one of the bearings to be suitably insulated with arrangements to access the insulation of the generator bearing while the machine is in operation. Insulating material to be non-hygroscopic epoxy glass laminate.
- e) Bearing instrumentation Redundant pick-ups/ transducers to be provided for assessing bearing vibration, metal temperature, drain oil temperature.
- ix) *Shaft Seals (if applicable)*
 - a) Type Ring type, to be provided at both ends and designed in such a way that minimum oil comes in contact with hydrogen during operation to minimize contamination.
 - b) Sealing ring lining Face of the sealing ring to be lined with babbitt metal or as per manufacturer's standard and proven practice.
 - c) Insulation Shaft seals and associated piping to be insulated to prevent circulation of shaft current as per manufacturer's standard practice.
- x) *Hydrogen Coolers*
 - a) General To be provided with 10% extra tubes. Cooler to be designed for at least 10 kg/cm² gauge pressure on the gas side irrespective of a lower normal operating casing pressure.
 - b) Cooler tubes Corrosion resistant with integral fins and arranged in the stator casing so as to avoid the direct fall of water during leakage, if any, on the winding insulation.
 - c) Water pressure in coolers Shall be maintained below the operating hydrogen pressure in the generator casing.
 - d) Temperature control Necessary control system including temperature sensing elements, control valves and devices shall be provided. Adequate number of temperature and pressure gauges shall also be provided on inlet and outlet of cooling water, in case water cooled machine is offered.



- xi) *Generator Drying Arrangement* Suitable equipments, accessories and controls shall be provided to enable drying out operation of the generator as per manufacturer's standard and proven practice.
- xii) *Temperature Detectors*
- a) Type Thermo-couples/ Resistance temperature detectors (RTDs) of duplex 100Ω platinum, calibrated as per DIN and/ or equivalent International standard and located at points, where highest temperature likely to occur during operation. Simplex type thermo-couples/ RTDs are acceptable with double the nos.
- b) No. and location
1. 12 no. detectors, 4 nos. per phase and uniformly distributed along the circumference of the stator and located at the hottest possible zones viz. the point of exit of stator water from winding in a water cooled machine.
 2. Detectors for monitoring water temperature of each winding bar in case of water cooled machine.
 3. 12 no. detectors for stator core, out of which 6 nos. to be located in the end zones where maximum temperature are expected.
 4. 2 no. detectors per hydrogen gas cooler section for measurement of inlet and outlet gas temperature.
 5. 2 no. detectors per hydrogen cooler section for measurement of inlet and outlet water temperature at water supply header piping or as per manufacturer's standard practice.
 6. 2 no. detectors per bearing for measurement of babbitt metal and drain oil temperature.
 7. Sets of detectors for generator shaft sealing, hydrogen gas and stator water systems required for monitoring the temperature of oil, water and hydrogen at different salient locations in the system.



xiii) Shaft grounding and voltage monitoring	Shaft riding brushes for shaft grounding and voltage monitoring system complete with all software and hardware to be provided as per manufacturer's proven practice.
xiv) Stator winding bars water temperature monitoring	On line monitoring system complete with all software and hardware and as per manufacturer's proven practice to be provided to detect any abnormalities in the temperature for individual stator bars.
xv) Rotor winding temperature monitoring (for static excitation system)	Suitable arrangement as per manufacturer's proven practice to be provided for rotor winding temperature measurement.
xvi) Rotor flux monitoring	Sensors for to be provided complete with all software and hardware to detect turn to turn shorting in field winding.
xvii) Partial discharge monitoring	Sensors for to be provided for on-line partial discharge (PD) monitoring complete with all software and hardware.
xviii) Vibration monitoring (if required)	Optical sensors (at least 6 nos.) for vibration pickups at each end of over hang portion of the winding to be provided.
xix) Liquid leakage detector	To be provided at all the low level points inside the generator casing including end shields.

16.2 Generator Auxiliary Systems

16.2.1 Gas system (for hydrogen and water cooled machines)

i) General	Each generator to be provided with H ₂ and CO ₂ gas supply system including gas manifolds, CO ₂ heating system (if necessary), hydrogen pressure regulator, etc.
ii) Requirement of gas cylinders	Requirement for one start-up and one shut-down of a unit plus those required to be connected on manifolds of all the units plus total requirements for 7 (seven) days consumption of all the units to be furnished.
iii) Hydrogen driers	2x100% duty to maintain the H ₂ inside the machine dry with 0 ⁰ C dew point at operating pressure with provisions to prevent condensation.



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|-------------------------------|-------------------------------|--|
| iv) | Dryer type | Reactivation/ Refrigeration/ Manufacturer's practice. |
| v) | Valve inter-locking | 3-way valve used along with the drier for interconnecting the H ₂ and air line (as applicable) preferably have mechanical inter-locking, such that closing of the H ₂ side port is positively ensured before opening of the air side port. |
| vi) | On-line dew point measurement | To be provided across the inlet and outlet lines to the drying system. |
| vii) | Gas analyser | To be provided with thermal conductivity/ gas density based type to continuously analyze the gas discharged from the casing during purging and also analyze samples of the casing H ₂ during normal operation.
The analyzer to measure the gas purity under the following three conditions :
a) Normal percentage of purity of H ₂ in air in the generator casing. Purity range to include a low purity alarm.
b) Percentage of H ₂ in CO ₂ leaving the casing when H ₂ is being admitted or expelled.
c) Percentage of air in CO ₂ leaving the casing when CO ₂ is being admitted or expelled. |
| viii) | Portable gas analyzer | Similar as detailed above under clause "Gas Analyzer" to be provided for supervision of the gas purging operation. |
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| 16.2.2 Seal oil system | | |
| i) | General | A complete seal oil supply and control system including AC and DC motor operated pump sets, coolers, etc. |
| ii) | Number of pumps | 2x100% AC motor driven pumps. 1 no. 100% DC motor driven pump. |
| iii) | Emergency condition | During short time emergency, which may arise due to non-availability of both AC and DC pumps, unit may be tripped and seal oil supply for such coasting down period shall be from a suitable arrangement from lubrication oil system or a damper tank or as per manufacturer's proven practice. |



- iv) Coolers (if applicable)
 - a) 2x100% duty seal oil coolers.
 - b) Cooler tube/ plate redundancy: Seal oil coolers to be designed to have 15% excess cooling surface area over and above designed tube surface area required for the rated load conditions, while maintaining the design pressure drop on cooling water side.
- v) Filters Suitable filters of 2x100% duty to be provided.

16.2.3 Stator water cooling system

- i) General Cooling of stator winding to be provided with a closed loop stator water cooling system.
 - a) Primary water tank One (1) no. tank mounted on generator casing with anti-vibration pads or mounted separately. The empty space in primary water tank may be filled with N₂ or H₂ (or air in case of oxygen rich type system) to minimize water evaporation. Devices to be provided to detect, trap, monitor and release the H₂ that leaks in to the stator water cooling system, to a safe place outside the building through suitable safety valves.
 - b) Water to water heat exchangers 2x100% or 3x50% capacity shell and tube type or plate type water to water heat exchangers designed to accept secondary DM water (condensate quality). The exchanger to be designed to have 10% excess cooling surface area over and above the designed surface area required for the rated load condition, while maintaining the design pressure drop on cooling water side.
 - c) Filters 2x100% capacity fine wire mesh filters with magnet bars of unlimited life for removal of all magnetic particles. Permanent magnet bars to be protected by sleeves of stainless steel. Alternatively, manufacturer's standard and proven practice regarding type of filter shall also be acceptable.
 - d) Circulating water pumps 2x100% capacity AC motor driven.



- e) De-mineraliser One (1) mixed bed demineraliser (MBD) of adequate capacity to maintain the required quality of water. MBD to remain continuously in service in order to retain high purity of stator cooling water with its associated electrical resistivity.
- ii) On-line monitoring system for water quality Required for ensuring a corrosion free operation to be provided along with stator water system.

16.2.4 Generator excitation system

- i) General The generator shall be provided with 'Static Excitation System' or 'Brushless Excitation System' along with 'Automatic Voltage Regulator'.
- ii) Design and construction
 - a) General When the generator is subjected to a sudden loss of rated output at rated power factor, the system shall be capable of restoring the voltage within 2% of the nominal preset value within negligible time prior to initiation of protection equipment.
 - b) Redundancy The redundancy shall be as follows :
 1. Static excitation system:

Power thyristor converter shall be fully controlled three phase, full wave bridge type with fast and high ceiling performance. The converter shall have 'N+2' redundancy where N is the number of bridges required to deliver rated excitation current and 'N+1' number of bridges shall deliver the ceiling voltage/current.
 2. Brushless Excitation System :
 - Converter assembly of pilot excitation system, thyristor gate firing system & pulse transformer shall have 2x100% redundancy.
 - The rotating rectifier assembly shall be of one complete bridge as redundant. Alternatively, a single three phase rectifier bridge with atleast one redundant parallel branch in each of six branch of the bridge shall be provided.



- c) Margin Each excitation system channel shall be designed to continuously carry at least 110% of the rated machine excitation current at the rated output of the machine and higher currents for short time duty. Short time duty as mentioned above shall be on MCR base as per clause 1.14 of part III in VDE 530.
 - d) Excitation system response time <0.5 sec (as per IEEE 421 A).
 - e) Excitation response ratio >2
 - f) Excitation system ceiling voltage >1.5 times rated load excitation voltage.
 - g) Field forcing capability Each excitation system channel shall be capable of supplying without damage to any of the components, the field forcing voltage and current of the system for a period of 10 seconds without exceeding the limits of temperature for rectifier junction and sink, when the equipment starts at normal operating temperature.
- iii) Automatic voltage regulator (AVR)
- a) Voltage regulator The excitation system shall be designed in such a manner that due to any single fault in AVR firing circuit pulse transformer, rectifying elements in any channel etc. excitation system shall be available with its full capacity. All rectifying elements shall have over voltage and short circuit protection.
 - b) Number of channels Two numbers fully equipped automatic channels having independent inputs and automatic changeover shall be provided. Either channel shall be capable of being the main or standby. Either channel shall be capable of being selected as manual also.
 - c) Characteristics
 1. Auto control range (\pm)10% of rated terminal voltage in all modes for voltage level adjustments of generator operation.
 2. Frequency range of operation 47.5Hz to 51.5Hz.
 3. Accuracy at which generator voltage to be held Better than 0.5% of the set value over the whole load range of the generator.



- | | |
|---|---|
| 4. Range of transformer drop compensation | 0 to 15%. |
| 5. Maximum change in generator voltage | <0.5% (when AVR is transferred from auto to manual under all conditions of excitation). |
| 6. Manual control range | 70% of no load to 110% full load excitation. |
| d) Technical features | The AVR shall be provided with minimum following features: |
| 1. Channel reference control | Solid state microprocessor control. |
| 2. Ramp generation circuit | To enable gradual rise of reference signal applied to the comparator circuit to avoid sudden voltage build up. |
| 3. Transformer drop compensation | Suitable feedback proportional to transformer drop to be provided for compensation. |
| 4. Limiters | Limiters but not limited to following to be provided: <ul style="list-style-type: none">- Over excitation limiters- Under excitation limiter- Rotor angle limiter (if required)- Stator current limiter (if required)- Rotor Current limiter- Voltage/ frequency (V/F) limiter |
| 5. Power system stabilizer (PSS) | The excitation system shall be provided with power system stabilizer for achieving the dynamic stability of the system under most stringent conditions of operation in the phase of disturbance created by short circuits conditions, load rejections, switching on/ off of transmission lines as per manufacturer's practice. |
| iv) Rotor earth fault detection | Two stage rotor earth fault unit for continuous monitoring along with alarm and trip contacts. |
| 16.2.5 Stability studies | The detailed computer studies shall be carried out by the supplier considering single machine with infinite bus so as to confirm the suitability of the turbine generator and its excitation system in the grid for maintaining the power system stability under dynamic and transient conditions and tune the PSS parameters at site for all the machines. The details of simulation technique and method proposed to be used for this purpose shall be furnished. |



SECTION-4

*CONTROL AND
INSTRUMENTATION
SYSTEM*



CHAPTER- 17

CONTROL AND INSTRUMENTATION

17.1 General

17.1.1 General requirements

- i) A totally integrated Instrumentation and Control System shall be provided ensuring operability, maintainability and reliability. The Instrumentation and Control System shall be consistent with modern power plant practices and shall be in compliance with all applicable codes, standards, guideline, statutory regulations and safety requirements in force.
- ii) Each component and system offered shall be of established reliability. The minimum target reliability of each piece of equipment like each electronic module/card, power supply, peripheral etc. shall be established, considering its failure rate/mean time between failures (MTBF), meantime to repair (MTTR) such that minimum availability of the 99.7% is assured for complete C&I system.
- iii) Adequate redundancy in system design shall be provided at hardware, software and sensor level to satisfy the requisite availability criteria. For boiler and turbine protection systems, independent sensing device shall be provided to ensure adequate safety of plant equipment.
- iv) It shall be ensured that all instruments/devices are preferably of the same make, series and family of hardware so as to ensure smooth and optimal maintenance, easy interchangeability and efficient spare parts management of various C&I instruments/equipment. For example, all 4-20mA electronic transmitters/ transducers, control hardware, control valves, actuators and other instruments/ local devices etc. for steam generator, turbine generator and other auxiliaries shall be of the same make and series for similar applications, except for the instrument integral to TG, boiler and BFP which may be manufacturer specific.

The equipment shall employ latest state of the art technology to guard against obsolescence.

- v) The design of the control systems and related equipments shall adhere to the principle of 'Fail Safe' operation wherever safety of personnel / plant equipment is involved. 'Fail Safe' operation signifies that the loss of signal or failure of any component shall not cause a hazardous condition. However, it shall also be ensured that occurrence of false trips are avoided/ minimised.



17.1.2 Unit control & monitoring philosophy

i) The control & monitoring of the plant is envisaged from two locations:

a) From Unit Control Room (UCR)

There shall be one common UCR for controlling the boilers, turbine-generators and unit auxiliaries. Accordingly, the layout of UCR shall be developed to accommodate the complete control equipment associated with each unit and the control interface equipment for common facilities of the plants.

b) From local control stations for auxiliary plants and off site plants.

ii) *Control & Monitoring from Unit Control Room*

a) The main plant equipment (namely steam generator & auxiliaries, TG & auxiliaries, regenerative cycle equipment, equipment cooling water system etc.) is envisaged to be controlled from the operator workstation (OWS) mounted on the unit control desk (UCD) in the unit control room (UCR) under all regimes of operation i.e. start-up, shutdown, load throw off and emergency handling. In addition, minimum 4 nos. large video-screens of minimum size of 170 cm (67") per unit shall be provided. In addition to the operator work stations (OWS) & large video screens (LVS) mentioned above, minimum amount of back- up instrumentation viz. conventional push-button (PB) stations and status indicators shall be provided for safe shut down of the unit.

b) Operation of generator, generator auxiliary systems and breakers for 11kV (unit and station switchgears), 3.3 kV switchgear and 415 V associated with the main plant and DG sets shall also be performed through OWS.

c) The operation of CW pumps shall be integrated in DDCMIS with a provision for operation of CW pumps from unit OWS as well as from local control panel/ local push button station to be provided in the CW pump house.

iii) *Control & Monitoring of the Auxiliary Plants*

The control, monitoring & operation of the auxiliary plants (i.e. ESP system, centralized oil purification system for TG, condensate polishing system etc.) shall be carried out from local control panel/operator workstation of the respective plants. For all such plant information link shall be provided for collection of data in the DDCMIS in UCR for the information of unit in-charge /shift-in-charge etc.



iv) *Control & Monitoring of Off Site Plants*

The control, monitoring and operation of the off-site plants i.e. coal handling plant, ash handling plant, fuel oil plant, D.M. plant etc. (not forming part of BTG system) shall be carried out from the local control panel/operator work station. All hardware and software shall be provided at BTG end for establishing a link for collection of data in the DDCMIS in UCR through soft link. However, as stated above, CW pumps shall be operated from unit OWS as well as from local control panel in CW pump house.

17.1.3 Environmental conditions

Instruments, devices and equipments shall be suitable for continuous operation in the operating environment of a coal fired station and shall be designed for ambient temperature range of 5⁰C to 55⁰C and RH of 5% to 100% (95% for indoor location). For air conditioned areas, normal temperature shall be considered as 24⁰C +/- 5⁰C and RH in the range 5% to 95%.

17.2 Distributed Digital Control, Monitoring and Information System (DDCMIS)

The microprocessor based integrated distributed digital control, monitoring & information system (DDCMIS) shall be provided for the safe and efficient operation of steam generator, turbine generator and all auxiliaries under all regimes of operation.

The DDCMIS shall basically consist of:

- i) Control system of boiler, turbine & balance of plant (namely SG- C&I, TG- C&I & BOP- C&I including their respective measurement systems).
- ii) Man-Machine interface and plant Information system (MMIPIS).
- iii) System programming, maintenance & documentation facility.
- iv) Data communication system (DCS).
- v) Sequence of events (SOE) recording system.
- vi) Annunciation system.
- vii) Master & slave clock system.

17.2.1 General requirements

i) *System Expandability*

Modular system design shall be adopted to facilitate easy system expansion through the addition of controller modules, process I/O cards, drive control modules, push button stations, peripherals like TFT/Keyboards, printers etc. The system shall have the capability to add any new control loops groups/subgroups in control system while the existing system is fully operational.



ii) *On- Line Maintenance*

It shall be possible to remove/replace online various modules (like I/O module) from its slot for maintenance purpose without switching off power supply to the corresponding rack. Further, it shall also be possible to remove/replace any of the redundant controller module without switching off the power to the corresponding rack and this will not result in system disturbance or loss of any controller functions for main controller. The on-line removal/insertion of controller, I/O modules etc. shall in no way jeopardise safety of plant and personnel.

iii) *Fault Diagnostics*

The DDCMIS shall include on-line self-surveillance, monitoring and diagnostic facility so that a failure/malfunction can be diagnosed automatically down to the level of individual module giving the details of the fault on the programmer station TFT displays and printers. The diagnostic system shall ensure that the faults are detected before any significant change in any controller output has taken place. Failure of any I/O modules, controller etc. shall be suitably grouped and annunciated to the DDCMIS annunciation system.

iv) *Fault Tolerance*

The DDCMIS shall provide safe operation under all plant disturbances and on component failure so that under no condition the safety of plant, personnel or equipment is jeopardised. Control system shall be designed to prevent abnormal swings due to loss of control system power supply, failure of any control system component, open circuits/short circuits, instrument air supply failure etc. On any of these failures, the controlled equipment/ parameter shall either remain in last position before failure or shall come to fully open/close or on/off state as required for the safety of plant/ personnel/ equipment.

v) *Signal Exchange*

All the signal exchange between various functional groups of each control group (i.e. within SG - C&I, TG - C&I and BOP - C&I) shall be implemented through redundant main system bus (the main bus connecting various sub-systems) and local system bus within a sub-system as per the standard practice of the OEM. It shall be ensured that any single failure in electronics involved for such communication, e.g., communication controllers, bus interface modules, physical communication media, etc. does not result in loss of such signal exchange and there in no deterioration in specified system response and system parametric requirements. In case a controller utilises some inputs generated/ processed by any other controllers/functional group and the requirement of controller response time is not met due to inadequate communication rate/ procedure, then hardwired signal exchange shall be provided for such inputs.



Control & protection signal exchange between SG- C&I, TG-C&I and BOP - C&I shall be hardwired only. Protection signals like MFT shall necessarily be hardwired even for exchange within the same sub-system.

No single failure either of equipment or power source shall render any part/system/sub-system of DDCMIS in-operative to any degree.

vi) *Remote Input Modules and Cubicles*

The use of remote input modules and racks / cubicles at some locations in the plant such as boiler area (for metal temperature etc.), transformer yard (for various inputs related to transformers), CW pump house, IDCT (if applicable), FO pump house may be made to minimize cabling. The modules used for such application shall be designed to withstand the harsh environment expected to be encountered in respective plant areas.

17.2.2 Measurement functions of control system

All the signals coming into/going out of the control system shall be connected either directly or routed through marshalling cabinets as per the interconnection philosophy of DDCMIS. The input / output modules employed in the control system shall be separate from controller hardware.

i) *Analog Signal Conditioning & Processing*

a) The conditioning and processing functions to be performed as a minimum for the analog inputs coming for control and information purposes shall be:

1. Galvanic isolation of input and output signals wherever required.
2. Transmitter power supply with per point fuse protection or current limiting and power supply monitoring as per standard practice of the OEM.
3. Transducer/transmitter signal output limit check.
4. Implementation of multiple measurement schemes.
5. Square root extraction.
6. Pressure and temperature compensation.
7. Linearisation of thermocouple signals.
8. Reasonability check for all analog inputs.



- b) All analog signals for control purpose shall be acquired, validated, processed and their respective data base updated at a maximum interval of 250 milli-seconds except for some fast-acting control loops for which the above-referred time shall be as per process requirement. For signals required for information only, the above functions shall be performed at an interval of within 1 second.
 - c) The 4-20 mA input analog cards shall be suitable for interfacing transmitters giving 4-20mA analog signal along with superimposed HART interface signals. 4-20 mA DC signal will only be used for control purpose and superimposed HART signal will be used for configuration, maintenance diagnostic and record keeping facility for electronic transmitters and analysers etc. For non-HART 4- 20mA analog inputs, conventional non-HART AI module shall be applied.
- ii) *Binary Signal Conditioning & Processing*
- a) The changeover type contacts (i.e. 'NC' + 'NO' together) shall be wired to the control system for all the binary inputs required for control purposes, except for inputs from MCC/switchgear, actuators and inputs related to hardwired signal exchange among various functional group for which non-changeover type contacts ('NC' or 'NO') shall be wired to the control system. The binary inputs required for information purposes only shall be wired to control system in the form of non-changeover type contacts.
 - b) The conditioning and processing functions to be performed as a minimum for the binary inputs coming for control and information purposes shall be:
 1. 24V/ 48 V DC power supply for contact interrogation for all potential free contacts with per point fuse protection or suitable current limit feature/ isolation through opto-coupler.
 2. Contact bounce filtering delay time of 15 milliseconds.
 3. Facility for pegging the binary signal to logic one/zero or last correct value in case of failure of binary input module.
 4. Binary signal distribution to different users shall be in such a way so as to ensure that a short/ground fault on one user is not reflected to the other user.
 5. Implementation of multiple measurement schemes for signals for control purpose.
 6. All binary signals shall be acquired, validated, processed, alarm checked and their data base updated within one second. In addition to this requirement, binary signals required for SOE shall have a resolution of 1millisecond.



7. Facility to delete any binary input from scan or to return to scan on operator demand.

iii) *Triple Measurement Scheme*

- a) Triple measurement scheme for analog inputs employing three independent transmitters connected to separate tapping points shall be employed for the most critical measurements used in analog control functions including but not limited to furnace draft, feed water flow, turbine throttle pressure, turbine first stage pressure, deaerator level, turbine speed.
- b) Individual transmitter signal, their status and selected value for control/measurement shall be available on OWS.

iv) *Dual Measurement Scheme*

- a) Dual measurement scheme for analog inputs employing two independent transmitters, connected to separate tapping points/temperature element shall be employed for the remaining measurements used for analog control functions.
 - b) Individual transmitter signal, their status and selected value for control/measurement shall be available on OWS.
- v) For binary and analog inputs required in furnace and turbine protection, triple sensing devices shall be provided. Binary and analog inputs which are required for protection of more than one equipment (e.g. deareator level very low etc.) as well as protection signals for turbine driven boiler feed pump (TDBFP)/ motor driven boiler feed pump (MDBFP), triple sensing devices shall be provided. For other critical binary and analog inputs required for protection and interlock purpose of other equipment (e.g. those interlocks which may result in loss of generation, non-availability of a major equipment etc.), dual sensors shall be provided. However, for bearing temperature of FD/ID/PA fans, mills, APH, BFP, CEP and their HT drives, single sensor can be used.

17.2.3 Functional grouping of controllers

- i) Functional grouping of various controllers shall meet following general requirements:
 - a) Process redundancies shall be maintained. For example, in case the mechanical equipment has been provided with redundancy, the drive shall not be controlled by a common controller and it shall be ensured that there is no sharing of controller components between independent groups.



- b) Stream concept shall be maintained. The different equipment shall be clubbed in such a manner that failure of a controller set affects only one stream of the process path, e.g. in air and flue gas path, ID-fan A, FD-fan A, and rotary air pre heater– A can be clubbed on one set of controllers.
 - c) Inter-related controls shall be provided in one group, i.e. when the loop /sequence of one equipment depends on the availability of another sequence /loop or equipment than these controls shall be preferably be clubbed together e.g. PA fan controls depend on the availability of mills/mill control, so, control of half the number of mills can be clubbed with control of the relevant PA fan.
 - d) While formulating the controller groups, it shall be ensured that the failure of one function does not jeopardize the plant operation or cause shut down. For example if 6 mills are required for full load plant operation, then the grouping of mills shall be done in such a manner that not more than 3 mills shall be clubbed in one set of controller.
 - e) For each of the functional groups, separate sets of controllers, I/O modules, communication controllers, power packs/ modules etc. shall be provided. Mixing of hardware of two or more functional groups (FG) shall not be acceptable. It shall be ensured that failure of any set(s) of hardware of any FG does not affect other FG(s) and data communication between other FG(s) and MMIPIS.
- ii) The control system shall have on-line simulation and testing facility. Further, it shall be possible to on-line configure and tune controllers through configuration and tuning station for control system.
 - iii) The system shall have the flexibility to easily reconfigure any controller at any time without requiring additional hardware or system wiring changes and without disabling other devices from their normal operation mode. Modifications shall not require switching off power to any part of the system.
 - iv) The executive programs for the controller modules shall be firmware based, which shall be non-volatile and shall not be alterable except by replacement of parts. The application programs for the functional controllers shall be software based or firmware based as per OEM's standard practice.
 - v) All the 100% hot/redundant backup controllers shall be identical in hardware and software implementation to their corresponding main controllers and shall be able to perform all its tasks. The backup controller shall track its corresponding main controller. There shall be an automatic and bumpless switchover from the main controller to its corresponding backup controller in case of main controller failure and



vice versa without resulting in any change in control status. In case of switchover from main controller to the 100% hot backup controller, the back-up controller shall work as the main controller.

Facility shall also be provided for manual switchover from main to 100% hot back-up controller and vice versa from the programmer's console.

17.2.4 Binary controls/open loop control system (OLCS) function

- i) The OLCS shall include sequence control, interlock & protection for various plant auxiliaries, valves, dampers, drives etc. The sequence control shall provide safe and automatic startup and shutdown of plant and of plant items associated with a plant group. The interlock and protection system shall ensure safe operation of plant/plant items at all times and shall automatically shut down plant/plant items when unsafe conditions arise.
- ii) The OLCS shall be arranged in the hierarchical control structure consisting of group level, subgroup level & drive level (as applicable).

It shall be possible to perform automatic unit startup & shutdown by issuing minimum number of command from the OWS.

The group level shall control a set of functional sub-groups of drives. Appropriate start-up and shut down commands shall be issued to the sub-group control and various checkbacks shall be received from sub-groups or drives. Each sub-group shall execute the sequential start-up and shut down programmes of a set of inter-related drives along with system interlocks and protections associated with that sub-group as well as basic interlocks and protections related to individual drive falling under that sub-group. The drive level shall accept commands from the sub-groups, push buttons (wherever provided), etc., and transmit them to the respective drive, after taking into account various interlocks and protections and the safety of that particular drive.

- iii) A sequence shall be used to move a set of groups and sub-groups from an initial steady state (for instance 'OFF') to a final steady state (for instance 'ON'). The sequence initiating command for the unit and group level shall be issued from TFT/KBD.
- iv) Manual intervention shall be possible at any stage of operation and the sequence control shall be able to continue at the correct point in the programme on return to automatic control. Protection commands shall have priority over manual commands, and manual commands shall prevail over auto commands.
- v) Open or close priority shall be selectable for each drive.



- vi) The sequence of startup mode shall be of the following types:
- a) *Automatic mode*

In this mode of operation, the sequence shall progress without involving any action from the operator. The sequence start/stop command shall be issued from the TFT/KBDs.
 - b) *Semi-automatic mode*

In this mode of operation, once the sequence is initiated, the step progressing shall be displayed on the TFT. But the step execution command shall be prevented and shall be sent by the operator via the keyboards. It shall be possible to bypass and/ or simulate one or more criteria to enable the program to proceed. All the criteria bypassed shall be logged and displayed. It shall be possible to put the system on the auto-mode after operating it on semi-automatic mode for some steps or vice-versa, without disturbance to the sequence operation.
 - c) *Operator test mode*

It shall be possible to use the sequential control in operator guide mode/ test mode i.e. the complete system runs and receives input from the plant and the individual push button stations (where provided)/ keyboards but its command output is blocked. The whole programme, in this case shall run in manual mode. This mode shall allow the operator to practise manual operation using step and criteria indications. The actual protection should remain valid during this mode of operation also.
- vii) For the HT and critical LT drives, the command shall be provided through redundant output module and inputs (status, switchgear & process) shall be acquired through input modules. The drive logic shall be implemented in the redundant controller.
- The status for the 11 kV, 3.3 kV drives and other selected important drives shall also be wired in parallel to redundant input modules so that on failure of the single input modules, the information regarding the status of the affected drive remains available in OLCS.
- viii) The output modules control module shall have the feature that ensures that in case of failure, all the outputs are driven to zero. The 24V DC command outputs to drives for on/open, off/close shall be separate and independent and inverted outputs shall not be employed. For inching type of drives, position transmitter power supply and monitoring of position transmitter signal shall be provided.
- ix) The OLCS shall also include the control of electrical systems in addition to the auxiliaries of boiler & turbine such as open/close or on/off etc. of various electrical systems such as generator, generator auxiliary systems, breakers of 11kV, 3.3 kV, 415 V switchgears,



synchronisation of unit etc. All the features and requirements as indicated above shall also be applicable for electrical system.

17.2.5 **Analog controls/closed loop controls system (CLCS) functions**

The CLCS shall continuously act on valves, dampers or other mechanical devices such as hydraulic couplings etc., which alter the plant operation conditions. The system shall be designed to give stable control action in steady state condition and for load changes in step/ramp over the load range of 50% to 100% MCR with variation or parameters within permissible limits. The system shall have the following minimum features:

- i) The controller capability shall, as a minimum, include (a) P, PI, PD and PID control functions and their variations (b) cascade control (c) feed forward control (d) state-variable based predictive control for SH/RH temperature control (e) on-off control, (f) ratio and bias control, (g) logical operation etc.
- ii) The loop reaction time (from change of output of the sensor of the transmitter/temperature element to the corresponding control command output) shall be within 500 milli seconds. However, for faster loops such as feed water, furnace draft, PA header pressure control loop etc. the same shall be based on actual process requirement but shall not be more than 250 millisecond.
- iii) The controls shall be bumplessly transferred to manual mode on conditions such as failure of redundant control power supply, failure of redundant controllers, field input signal not available, analog input exceeding preset value, etc. as a minimum.
- iv) Any switchover from auto to manual and manual to auto shall be bumpless and without resulting in any change in the plant regulations and the same shall be reported to the operator.
- v) Buffered analog output (positioning signal) of 4-20mA DC shall be provided from CLCS to the respective E/P converters. For electrical actuators, pulse type output (bound less control) shall be preferred.
- vi) The system shall be such that when permissible limits are exceeded, an automatic switchover from an operation governed by maximum efficiency, to an operation governed by safety and availability is affected.

17.2.6 **Control system requirements**

The control system along with its measurement system shall perform functions of closed loop control, sequence control, interlock & protection of SG, TG and auxiliaries under all regimes of unit operation. The measurement system of control system shall perform the functions of signal acquisition, conditioning and signal distribution of various types of



inputs/outputs like analog (4-20 mA DC, thermocouple, RTD), binary, pulse, etc. The inputs which are required for only information and monitoring purposes shall be distributed suitably in various groups of the measurement system.

i) The control system shall be broadly divided into SG- C&I, TG- C&I and BOP- C&I.

a) The SG- C&I part of DDCMIS system shall perform the following function as minimum but not limited to:

1. Burner management system (BMS) including control & protection of coal mills, fuel oil system etc.
2. Analog control functions pertaining to separator drain control, secondary air damper control, auxiliary pressure reducing & desuperheating station (PRDS) pressure and temperature control.
3. Soot blower control.

b) The TG- C&I part of DDCMIS system shall perform the following functions:

1. Turbine protection system function (TPS).
2. Turbine governing system for main turbine.
3. Automatic turbine run up system. (ATRS).
4. Automatic turbine testing (ATT).
5. Turbine stress control system (TSCS).
6. HP&LP bypass control system (HP bypass control system may be alternatively implemented in SG- C&I part of the DDCMIS).
7. Electro-hydraulic governing system for BFP turbine.
8. Turbine generator control system.

The turbine protection system and electro- hydraulic governing system may be implemented as part of standard practice of the turbine manufacturer.

c) The BOP- C&I system shall perform the following functions:

1. Analog control functions other than those covered in SG-C&I and TG-C&I like co-ordinated master control, furnace draft control, SH/RH steam temperature control, feed water flow control, heaters/ deaerator/ condenser level control etc.



2. Binary control functions pertaining to main plant auxiliaries like FD/ ID/ PA fans, APH, BFP etc., generator auxiliary systems and electrical breakers etc. The generator auxiliary system can alternatively be implemented in TG C&I as per standard and proven practice of the OEM.

SG C&I

ii) *Burner Management System (BMS)*

- a) Fully proven microprocessor based system, based on hardware and software proven for burner management application shall be provided to achieve the boiler protection e.g. master fuel trip (MFT), control of mills & fuel oil systems etc. The BMS shall meet all applicable relevant safety requirements including those stipulated in latest editions of NFPA 85. The MFT subgroup of BMS shall comply with relevant requirements of EN 50156, IEC 61508/ 61511.
- b) The BMS shall be provided with automatic self monitoring facility. All modules to be used in this system shall be of fail safe design. Any single fault in any primary sensor, I/O modules, multifunction controllers, power supplies, cables etc. should not result in loss of safety function. All faults should be annunciated to the operator, right at the time of its occurrence.
- c) The MFT functions shall be implemented in a true triple modular redundant (TMR) configuration i.e. each of the three channels shall have its own dedicated processors, controllers, communication, I/O modules, interface etc. All safety related process inputs shall be fed to each of the 3 channels. All the primary sensors for unit/boiler protection shall be triple redundant. The TMR system shall be SIL compliant.
- d) The acquisition and conditioning of binary and analog protection criteria signals for MFT shall be carried out in each of the three triple redundant channels. Each channel shall compute the 2 out of 3 voting logic and issue a trip command. The trip signals of the three channels shall be fed to a fail safe 2 out of 3 relay tripping unit for each drive. The protection criteria for tripping shall be executed by a program which shall be identical in each of the triple redundant channel. The check back contact signals of each relay of the 2 out of 3 relay tripping unit shall be fed back to each of the triple redundant channels and shall be continuously monitored for equivalence in each of them.
- e) The BMS shall be designed to:
 1. Prevent any fuel firing unless a satisfactory purge sequence has first been completed.



2. Prevent start-up of individual fuel firing equipment unless permissive interlocks have first been satisfied.
3. Monitor and control proper equipment sequencing during its start-up and shutdown.
4. Provide equipment status feed back and annunciator indication to the unit operator.
5. Provide flame monitoring when fuel-firing equipment is in service and effect a burner trip or master fuel trip upon warranted firing conditions.
6. Continually monitor boiler conditions and actuate a master fuel trip (MFT) during adverse operating conditions which could be hazardous to equipment and personnel.
7. Reliably operate and minimize the number of false trips.
8. Provide a master fuel trip relay independent of processors and I/O modules to provide a completely independent trip path.
9. Provide all logic and safety interlocks in accordance with National Fire Protection Association (NFPA).
10. Include a first out feature in all controllers to identify the cause of any burner trip or boiler trip.
11. Provide a complete BMS diagnostic system to immediately identify to the operator any system module failure.
12. Allow burners and igniters to be started, stopped and tripped on a burner basis.

iii) *Secondary Air Damper Control (SADC) System*

- a) SADC system shall be provided to achieve the following functions:
 1. Control of fuel air flow.
 2. Control of auxiliary air flow at the oil elevations.
 3. Control of wind box/furnace differential pressure.
 4. Limit NO_x content in the flue gas by modulating over fire dampers, if provided.
- b) In case of tangentially fired boiler, SADC shall modulate fuel air dampers of each elevations based on the signal that is representative of the coal feed rate. Further, the auxiliary air dampers at the oil



- elevations shall be modulated on fuel oil pressure signal whereas the auxiliary air dampers at all other elevations shall be modulated to maintain the wind box to furnace differential pressure.
- c) In order to limit the NO_x content in flue gas, SADC shall also include the control of over-fire dampers (if provided). The secondary air damper controls and necessary interlocks to modulate or to open/close shall be incorporated as per the requirements of the boiler design.
 - d) Individual position transmitters are to be provided for each of the secondary air dampers and the same shall be connected to SADC System.
- iv) *Auxiliary Pressure Reducing and De-superheating Station (Aux. PRDS) Control System*
- a) Auxiliary PRDS control system shall be provided to control the low capacity PRDS (with steam tapping off from CRH line) and the high capacity PRDS (with steam tapping off from MS line) and coordinate their operation under all regimes of unit/plant operation.
 - b) Each of the aux. PRDS units (i.e. low capacity PRDS and high capacity PRDS) shall be provided with automatic control loops for steam pressure control, steam temperature control and spray water pressure control. However, facility for remote manual control shall also be provided for operation in case the automatic control fails. The signals for steam pressure and temperature control shall be taken from the down-streams of pressure reducing valve and de-superheating station respectively and their set points shall be adjustable. The spray water pressure control shall regulate the pressure upstreams to the temperature control valve and also based on feed forward signal from steam temperature control.
- v) *Soot Blower Control System (SBCS)*
- a) The soot blowing system shall be fully automatic & sequentially controlled through SG C&I control system. Alternately, a SMART soot blowing system based on heat flux sensors and flue gas exit temperature may be implemented with a fall back to sequential control, if required. The system shall be complete with provision for individual operation of any soot blower and facility to bypass any soot blower and shall be provided with following:
 - 1. Automatic starting of each soot blower in the system.



2. Canceling the operation of any soot blower in the system when required.
 3. Indication of the soot blower-selected to operate.
 4. Capability to monitor all the essentials of the soot blowing system.
 5. Capability to prevent continued soot blower operation if the system is not functioning properly.
 6. The ability to operate two soot blowers located in opposite walls simultaneously.
 7. Manual over-riding of the automatic operations.
 8. To prevent automatic blowing when the parameters of soot blowing system are beyond permissible limits.
 9. Indications of soot blower which has malfunctioned.
 10. Control circuit for the retractable blowers shall be so designed as to prevent insertion of the blowers into the combustion chamber unless the blowing medium is available.
- b) Soot blower control system shall also provide for control of blowing steam pressure, steam temperature (if required) and warm up of the complete piping system.

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vi) *Turbine Protection System (TPS)*

Fully proven microprocessor based system, based on hardware and software proven for turbine protection application for the same turbine as being offered, shall be provided to achieve the turbine protection action. The turbine protection system shall be as per requirements indicated below or can be implemented as part of standard and proven practice of the turbine manufacturer:

- a) The Turbine Protection System shall meet all applicable safety standards/requirements including those stipulated in latest edition of IEC 61508 and IEC 61511 or VDE 0116 Section 8.7, VDE 0160 etc. The system design shall be such that safety function of the total system must not be jeopardized on occurrence of fault. Any single fault in either primary sensor, input/output modules, controller module etc. shall in no way jeopardise the safety of the turbine. All modules to be used in this system shall be of fail safe design.



- b) The Turbine Protection System shall be implemented in 2 out of 3 voting logic. Three independent trip channels each having its own dedicated processing modules, controllers, input/output modules etc. shall be provided to achieve 2 out of 3 voting logic. The outputs of the three channels will be used to implement 2 out of 3 voting logic in two relay units, the output of which will be fed to the two turbine trip relays.

As an alternative, two independent trip channels may be proposed, each having its dedicated and hot redundant processing modules, controllers and I/O modules. Two out of three voting logic will be implemented in each of the channels and the output of each channel to be fed to each of the two turbine trip relays.

Turbine shall be tripped when either of the above two trip relays operates.

- c) All trip signal inputs required for the safety of the turbine shall be based on 2 out of 3 logics. The system shall include turbine lock-out relays, redundant turbine trip solenoids and necessary hardware required for testing.
- d) The tripping devices shall be designed to operate on DC supply. The trip coils shall be monitored continuously for healthiness and failure shall be alarmed.

vii) *Turbine Governing System for Main Turbine*

Fully proven microprocessor based system, based on hardware and software proven for turbine governing application for the same turbine as being offered, shall be provided to achieve the turbine governing action. The turbine governing system shall be as per requirements indicated below or can be implemented as part of standard and proven practice of the turbine manufacturer:

- a) The turbine generator unit shall be equipped with electro-hydraulic governing (EHG) system backed-up by mechanical-hydraulic control system. The system shall be designed such that the governing of the steam turbine shall be automatically and safely transferred to mechanical hydraulic control system during operation, in the event of a fault developing in electro-hydraulic control system. Alternatively, the EHG system shall be provided with 100% hot redundancy i.e. the system shall consist of two independent channels right from sensors, transmitters, other field mounted devices, input modules, controller modules, output devices etc. of the electro hydraulic converter. Further, each of these channels shall be fed from independent power supplies.



- b) The turbine governing system shall meet the following functional requirements:
1. The controls covered in this system shall basically consist of speed controller, load controller, overspeed protection controller, valve-lift controller, inlet steam pressure controller and output frequency droop characteristic controller. The speed controller shall ensure controlled acceleration of the turbine generator and shall prevent overspeed without tripping of the unit under any operating condition or in the event of full load throw-off.
 2. The speed controller shall limit the overspeed of the turbine on loss of full load to a value less than overspeed protection set point value. The governing system shall be equipped with speed/load changer to control the speed or power output of the steam turbine within the limits. The speed/load changer provided shall be capable of adjusting the speed of the turbo set to any value in the range of 94% to 106% of rated speed for manual/auto synchronisation of the generator with the bus. It shall be capable of varying the load on the machine from no load to full load.
- c) The governing system shall be capable of being operated remotely from unit control room for the purpose of limiting the amount of opening of the governor controlled valves to set the load at a pre-determined limit, while the turbine is in operation.

viii) *Automatic Turbine Run- up System (ATRS)*

ATRS shall run the turbine automatically from zero speed to synchronising speed and then load the machine upto block loading and continuously check the operation upto 100% MCR without impairing the life of the turbine. The automatic turbine run up system shall be designed to provide for the following functions:

- a) Automatic start up/shut down sequence.
- b) Stress/temperature margin controlled acceleration as per the pre selected mode i.e. slow, normal and fast.
- c) Stress/temperature margin controlled loading/unloading.
- d) Automatic synchronisation and loading upto 100% MCR.
- e) Unloading and shut down of the machine.

ix) *Automatic Turbine Testing (ATT) System*

ATT system shall be provided for on- load testing of turbine protective equipment automatically in a sequential manner without disturbing



normal operation and keeping all protective functions operative during the test. The ATT facility shall include but not be limited to the following:

- a) Opening and closing of emergency stop and control valves, reheat stop and interceptor valves.
- b) Over-speed trip.
- c) Low vacuum trip.
- d) Electrical remote trip.

ATT mentioned at item b), c) & d) above shall be possible to be carried out on 100% load.

The standard and proven practice of the OEM shall also be considered in respect of the above.

x) *Turbine Stress Control System (TSCS)*

A proven turbine stress control/ evaluation system shall be provided which will work in conjunction with turbine governing system and ATRS. The system shall be complete including measuring transducers for generator load, processing modules, microprocessor based controllers for stress calculations and turbine life calculations etc., colour TFT monitor, recorders, etc. The TSCS shall meet the following functional requirements:

- a) Continuous on-line monitoring of thermal stress levels in all critical parts of the turbine such as main stop valves, control valves, HP casing, HP shaft and IP shaft etc.
- b) Continuous on line computation of stress margins available for the above mentioned critical components of the turbine during various regimes of operation i.e. run-up, synchronisation, loading, load maneuvering, normal operation, run backs, unloading, shut-down etc.
- c) Computation of the limits of speed and load changes allowable at any particular instant before synchronisation and after synchronisation respectively. The system shall be designed to inhibit further operation like speed/steam temperature raising or lowering wherever upper/ lower temperature margins are not available (during periods prior to synchronisation) and load/steam temperature raising or lowering whenever upper/lower load/temperature margins are not available (after synchronization) within allowable limits.



- d) Carry out a fatigue analysis for all affected components of the turbine and also to compute the percentage service life consumption of the turbine.
- e) Display the stress margins etc. on OWS for operator guidance and storage of necessary data such as percentage service life consumption etc.
- f) Store long term data & carry out residual life analysis.

The standard and proven practice of the OEM shall also be considered in respect of the above.

xi) *HP&LP Bypass System*

- a) *HP bypass control system:* The system shall consist of steam pressure control loop & steam temperature control loop. HP bypass system shall be implemented through a set of redundant controller modules, I/O modules etc. The system shall be supplied with redundant primary sensor and suitable interface with other TG - C&I controls like LP bypass, EHG etc. as per standard and proven practice of the OEM.
- b) *LP bypass control system:* The LP Bypass control system shall consist of steam pressure control loop and steam temperature/ steam enthalpy control loop. The LP bypass control shall be implemented through a set of redundant controller modules, I/O modules etc. The LP bypass control shall suitably interface with other TG control like HP bypass, EHG etc. as per standard and proven practice of the OEM.

xii) *Electro Hydraulic Governing System for BFP Drive Turbine*

- a) The BFP drive turbine speed shall be controlled by electro - hydraulic governor for stable and satisfactory speed control over full speed range from 0% to 100%. The electro-hydraulic governing system hardware shall be microprocessor based, with hot back up. The exact implementation shall be as per standard and proven practice of the OEM.
- b) The governing system shall be able to receive speed demand signal in auto mode from FW control loop and in manual mode from OWS. The system shall be controlled from TG- C&I or may be implemented as per standard proven practice of the OEM. The actual speed of the turbine shall be measured by three independent speed sensors and three independent speed measurement channels. The electro-hydraulic controller shall be designed in such a manner that the transfer between different steam sources takes place in a bumpless manner.



17.2.7 Man-machine interface and plant information system (MMIPIS) requirements

i) *General*

- a) MMIPIS shall be used primarily to act as operator interface for control operation of the plant and to perform plant supervisory, monitoring and information functions.
- b) MMIPIS shall employ high-performance, non-proprietary architecture to ensure fast access and response time and compatibility with other system.
- c) The plant data pertaining to one unit shall be available in the MMIPIS of the respective unit. Data from common system shall be available in the MMIPIS of all the units.

ii) *Operator Interface to the Control System*

- a) The operator interface of the MMIPIS shall consist of colour TFTs/ KBDs of OWS, colour ink-jet printers, colour plotter etc. Each OWS shall include one TFT, one keyboard and touch screen or mouse for ease of operation.
- b) The following features shall be provided as a minimum:
 1. All OWS of the MMIPIS shall be fully interchangeable i.e. all operator functions including control, monitoring and operation of any plant area on drive shall be possible from any of the OWS at any point of time without the necessity of any action like downloading of additional files. Each OWS shall be able to access all control information related data under all operating conditions including a single processor/computer failure in the MMIPIS.
 2. No single failure in MMIPIS shall lead to non availability of more than one OWS and two printers. In such an event i.e., single failure leading to non availability of any OWS, it shall be possible to operate the entire plant under all regimes of operation including emergency conditions from each of the other available OWS.
 3. All frequently called important functions including major control loop display shall be assigned to dedicated function keys of the keyboard for the convenience of the operator.
- c) The operator functions for control on each OWS shall as a minimum include control system operation, alarm acknowledge, call control displays, demand/printout of various displays, logs, summaries etc.



- d) The display selection process shall be optimised so that the desired display can be selected with the barest minimum number of key strokes / steps by the operator.

iii) *Plant Supervisory, Monitoring and Information Functions of MMIPIS*

The MMIPIS shall be designed as an on-line system and following minimum functions shall be performed by MMIPIS:

a) *Calculations*

1. Basic calculations: All the algebraic/ logical calculations related to analog points (e.g. sum/ difference/ average/ integration etc.), digital point (e.g. AND/ OR/ COMPARE etc.), transformations, flow calculations, time projection or rate of change calculations, frequency etc. shall be provided. All the calculated values of the plant shall be available in the database.
2. Performance calculations: The performance calculations shall use high level language calculations and shall be made using floating point arithmetic. The results of these calculations shall be available through data base for appropriate logs and operator displays. The performance calculations shall broadly comprise of plant/equipment efficiency calculations. The calculation shall be carried out at 30% unit load or higher. The calculation frequency shall be selectable from 10 minutes to 1 hour, with a step of 10 minutes.
3. Other calculations: These shall include variable alarm limit calculations, heat rate deviations and revenue calculations, frequency excursion time integration etc.

b) *Alarm monitoring and reporting*

The system shall display history of alarms in chronological order of occurrence on any of the OWS. The MMIPIS shall have the capability to store a minimum of 1000 alarms each with paging features allowing the operator to view any page.

c) *Displays*

Various displays on the TFTs shall as a minimum include P&ID displays or mimic, bar chart displays, X-Y & X-T plot (trend) displays, operator guidance message displays, group displays, plant start-up/shutdown message displays, generator capability curves, heat rate deviation displays, system status displays etc.



Other types of displays as applicable for convenience of operation shall be provided. However, the minimum quantity of major types of displays shall be as follows:

1. Control displays (group/sub-group/sequence/loop) 500
2. P&ID/ mimic display 200
3. Bar chart 100
4. X-Y/ X-T Plot 100
5. Operator guidance message 100
6. Plant starting/ shutdown guidance message 100
7. Other misc. displays 25
8. System status & other diagnostic displays on as required basis.

The system shall have adequate storage capacity for storing the last 72 hours of data at scan rate for a minimum 500 points (operator selectable) for use in trend displays.

d) *Logs/ summaries*

The system shall generate three basic types of reports/logs i.e., event activated, time activated and operator demand log & summaries. The system shall have the facility for viewing of time activated and operator demand logs/summaries on the TFT(s).

1. Event activated logs shall as a minimum include alarm log, trip analysis log, start-up - shutdown logs (Boiler start-up log, turbine run-up log, turbine shutdown analysis log/ turbine recall log) & control related logs.
2. Time activated logs shall as a minimum include shift log and daily logs. Each of these shall provide hourly record of a minimum 225 points sub divided into 15 groups.
3. Operator demand logs shall include, as a minimum, trend log, maintenance data log, summary log, performance logs and some selected special logs. The system shall be capable of generating and printing trend log for a minimum of 80 groups of 15 points each. Maintenance data log shall provide schedule of preventive maintenance and routine equipments inspection.
4. Various summaries shall include off scan summary, constants summary, point quality summary, substituted values summary, peripheral status summary etc.



e) *Historical storage and retrieval system (HSRS)*

The HSRS shall collect, store and process system data from MMIPIS data base. The data shall be saved online on hard disk and automatically transferred to erasable & removable type disk/ drive once in every 24 hours periodically for long term storage. The capacity of removable disk/ drive shall be sufficient to store at least one month data.

The data to be stored in the above system shall include alarm and event list, periodic plant data, selected logs/reports such as event activated logs, sequence event log, trip analysis log, start-up log etc.

The system shall provide operator function to retrieve the data from historical storage. The operator shall be able to retrieve the selected data on either colour TFT or printer and suitable index files/directories shall be provided to facilitate the same.

17.2.8 System programming, maintenance and documentation facility

The programmer stations shall be provided for on-line configuration & tuning of control system and on-line program development/ modifications in MMIPIS. In addition, latest state of the art work-station based system documentation facility shall be provided to retrieve, generate & document all system documentation, logics, control loops, cable interconnection, etc. to achieve paperless documentation for the complete plant.

i) *Control System Structuring/ Configuration/ Tuning Facilities*

- a) Structuring, configuring and tuning facilities shall be provided for structuring, modification, storing, loading, testing, tuning, monitoring, etc. of all the microprocessor based controllers of the control system. The configuration and tuning unit shall be hooked up with the system bus. In case different hardware is employed for different parts of control systems and it is not possible to provide structuring/ configuration and tuning of these from the same station, necessary number of stations shall be provided for the purpose.
- b) It shall be possible to configure the system with ease without any special knowledge of programming or high level languages. Control strategy shall be implemented using familiar and conventional automation function blocks (software implemented).
- c) On-line tuning of the control loops shall be possible without causing any disturbance in the execution of the control loops. Provision to store and retrieve on immediate and long term basis the system configuration, data base etc. on a storage device shall be included. Facility shall be provided to reload/download the system or controller module from the already stored data, on-line.



ii) *MMIPIS Program Development/ Modification and System Maintenance Facilities*

Standalone online system shall be provided for programme development/modification to achieve various functions including development, modification and testing of software of MMIPIS, generation and modification of graphics, logs, HSRS functions in an interactive manner, MMIPIS database modification/creations, downloading the software with associated data base from the console and other features necessary for system maintenance. All operator functions shall also be available on MMIPIS programmer station.

iii) *System Documentation Facility*

The system shall have the facility to generate the associated documentation for both the control system & MMIPIS. The documents, to be generated by the system shall include P&ID drawings, control loop drawings, sequence drawings, signal distribution list/drawings, system interconnection drawings, cabinets general arrangement drawings, measurement list, drive schedule, alarm schedule, system hardware and functional configuration drawings for displays, logs, trends, graphics etc. The system shall also include all required software and hardware tools for creating, modifying and printing CAD drawings to achieve paperless documentation for DDCMIS.

17.2.9 Data communication system (DCS)

The data communication system shall be provided for communication between control system and MMIPIS communication and signal exchange between various functional groups as well as communication between various units & off site / off line systems.

- i) The DCS shall include a redundant main system bus and local system buses for major subsystems with hot back-up and other applicable bus systems like cubicle bus, local bus, I/O bus etc except back plane which can be non- redundant. The DCS shall have the following minimum features:
 - a) Redundant communication controllers/ communication ports shall be provided to handle the communication between each functional group of controllers of control system and the system bus. Any failure or physical removal of any station/module connected to the system bus shall not result in loss of any communication function to and from any other station/module.
 - b) Built-in diagnostics shall be provided for easy fault detection. Communication error detection and correction facility shall be provided at all levels of communication. Failure of one bus and changeover to the standby system bus shall be automatic and completely bumpless and the same shall be suitably alarmed and logged.



- c) Data transmitting speed shall be sufficient to meet the responses of the system in terms of displays, control etc. under worst possible data loading condition and minimum 20% spare capacity shall be available for future expansion.
- d) UTP cables or coaxial cables or fibre optic cables shall be employed for system bus.
- e) In case of any distance or other limitation, provision of suitable repeaters, MODEMS, amplifiers, special type of cables like optical fibres etc., as required, shall be made to make the DCS fully operational.

ii) *Station LAN*

The servers/ ethernet LAN of the each unit shall be connected to a station wide ethernet Local Area Network (LAN). The PCs at various plant locations and PLC/PC based systems shall be connected to this station wide ethernet LAN through TCP/IP protocol. The station head/O&M head & shift in-charge shall be located in this LAN to monitor data of all units as well as of the common plants and off-site plants.

A server shall be provided for this station wide LAN. All networking functions of LAN, calculation including merit order calculation shall be performed in this server.

17.2.10 Sequence of events (SOE) recording system

- i) The DDCMIS shall be provided with sequence of events (SOE) recording system capable to scan and record events in the sequence of occurrence within a resolution of one (1) millisecond. That is, all SOE points entering status change shall be reported and time tagged within 1 (one) millisecond of their occurrence. Input card shall be equipped with digital filters with filter delay of minimum 4ms (identical for all points) to eliminate contact bounce such that field contact which is changing state must remain in the new state for successive 4 ms to be reported as one event. The start of data collection for SOE report shall be reported to OWS within 1 sec of SOE data collection initiation. The system shall also have provision of rejection of chattering inputs.
- ii) The system shall also include provision for historical storage and retrieval of SOE reports for 3 months period.
- iii) The SOE report collection shall begin on occurrence of change of status of any SOE point and shall be printed after an operator selectable time interval of 1 to 3 min. or 100 status changes have taken place after the first event. Adequate memory to accommodate 6 (six) SOE reports i.e., two buffers of 100 status changes each shall be provided. Seventh SOE report shall overlap the first SOE report memory and so on.



- iv) The SOE reports shall also include a list of major equipment trip in chronological order and include the points which initiated SOE collection.

17.2.11 Annunciation system function

Annunciation system shall be LVS based with top portion of all the LVS reserved for annunciation with 3/4 bands for different priority. It shall be implemented as an inbuilt function of the DDCMIS. The field contacts shall be acquired through DDCMIS only. The annunciation sequence logic shall be implemented as a part of the DDCMIS controllers.

17.2.12 Master & slave clock system

- i) Master and slave clock system shall be provided to ensure uniform time indication throughout the various plant facilities and time synchronisation between control system, MMIPIS, switchyard disturbance recorder, other PLCs etc.
- ii) The system shall be complete with receiving antennae (for receiving time from satellite & radio signal), receiver and associated electronics, redundant master clocks, slave clocks, interconnecting cables, cubicles, power supplies & any other accessories. Master clock system shall be designed to provide internal time reference if GPS signal from Antenna is not available. A provision shall also be kept for synchronisation of the master clock with some other identified source.
- iii) The master clock shall drive the slave display units. It shall be ensured that loss of any slave display unit does not affect the display of any other slave unit. The MMIPIS, shall be synchronised with the master clock once in every hour. The switchyard event recorder and other plant PLCs shall be synchronised with the master clock once every minute.
- iv) The master clock shall be located in the control room and shall have facility for automatic synchronising with external radio/ satellite signals.
- v) Adequate no. of, say 10 to 15 slave clocks shall be provided, to be located at the various plant sites.

17.3 SG & TG Related Other Control & Instrumentation Systems/ Equipments

17.3.1 Flame monitoring system

- i) Flame monitoring system shall be provided to detect the individual flame and to enhance the boiler/furnace safety, to avoid spurious and unwarranted trips and to increase operational reliability, availability and efficiency of the Steam Generator such that the consumption of fuel oil shall be reduced to optimal minimum.



- ii) Flame monitoring system shall be fail safe and easily maintainable which shall include flame detectors of proven design for the type of fuel, environmental condition and other conditions, of established reliability at all loads of the steam generator. It shall be designed to work under all adverse conditions such as wide variation in fuel/air input ratio, wide variation in fuel characteristics, variation in operating temperature, maximum temperature under interruption of cooling air supply. The system shall conform to NFPA recommendation and location of detectors as per NEC requirements.
- iii) Flame detectors shall be working on the dynamic and static properties of primary combustion zone of each type of fuel and flicker frequency of flame. It shall pick up only the flame to which it is assigned and shall not respond to the adjacent and background flame or other radiations generated in the furnace. The design shall also take into account the absorption by a coal shroud, recirculated dust or other deposition on the flame detector head. The complete system shall provide the discrimination between oil and coal flame. Intensity indicators for main flame shall be provided alongwith galvanically isolated 4-20 mA DC signals and hooked to SG DDCMIS.
- iv) The system shall be easily maintainable and include automatic self test facility at regular interval.
- v) A portable flame detector testing kit shall be provided with built in stabiliser, capable of simulating both oil and coal flame, and testing of flame detector head unit at field. The testing kit shall also have facility for testing all type of electronic cards as being used in the flame monitoring system.
- vi) In case of tangentially fired boiler, the flame detectors shall be arranged in such a manner that coal flame detectors are available for each coal burner of both above and below each coal burner and separate oil flame detectors shall be provided for each oil burner. In case of discriminating type flame detectors capable of detecting and discriminating both oil and coal flame, with the help of a single scanner, the same can also be utilised for monitoring both oil and coal flame. For any other type of firing i.e. non-tangential type the flame detectors shall be provided for each coal and oil burner responding only to the flame of its associated burner.
- vii) 2x100% scanner air fans, one AC operated and other DC operated, shall be provided to supply cooling air for the flame detectors.

17.3.2 Coal feeders control and instrumentation

- i) Coal feeders shall be provided with microprocessor based C&I system preferably using same family of hardware as that of DDCMIS.



- ii) Each coal feeder shall be provided with a minimum of two independent speed sensors, pulser units and associated amplifiers, etc. Output from the speed sensors shall be used to provide at least four number isolated 4-20 mA DC analog signals corresponding to coal flow rate in tons per hour and any other signals that may be required for the control of the coal feeder. In addition, one pulser unit shall also be provided with two pulse outputs-one for use in control system and the other for remote integrator.
- iii) All associated electronics like buffer amplifiers, frequency to current converters etc. shall be provided for each coal feeder with local and remote speed indicators and integrators. The speed sensors and pulser units shall be totally enclosed, fire, dust and weather proof, suitable for the service conditions.
- iv) The control cabinet shall be provided with reset push buttons and individual lights to signal the individual internal trip conditions.
- v) Each feeder shall be provided with a four position switch located at the feeder for remote off, local run (when there is no coal on conveyor) and calibration purpose.
- vi) All necessary paddle switches and other detectors to monitor coal on belt, feeder discharge plugged etc. should be provided to ensure safe operation of the feeders.

17.3.3 Electromatic safety valves

The electromatic safety valve shall be an automatic, electrically actuated pressure relief valve. It shall be possible to set the value for one percent or less differential between opening and closing pressure. The electromatic safety valve shall be provided complete with all accessories like pressure measuring devices, controller units, local PB station, solenoid assembly, impulse piping etc. Provision shall also be kept to operate the electromatic relief valves from the DDCMIS TFT/KBD. The operation of the valve shall be accomplished by operator command or by means of pressure sensitive element which shall precisely and automatically relieve the pressures within very close limits.

17.3.4 Furnace temperature probes

Two number of furnace temperature probes shall be provided before platen superheater and/or before reheater regions and shall be electrically operated, fully retractable type. The furnace temperature probes shall be furnished with complete actuating mechanism and all the logics required for the actuating mechanism. The probe shall be provided with position transmitters, limit switch and indicator for remote indication. Each temperature probe shall have a duplex thermocouple suitable for the measurement range. The logics for furnace temperature probes shall be implemented in the DDCMIS.



17.3.5 Acoustic pyrometers (if applicable as per OEM practice)

- i) Acoustic pyrometers are to be provided to determine the average flue gas temperatures and complete flue gas temperature profile at furnace exit plane (for FEGT measurements) and at economiser outlet.
- ii) For each temperature measurement plan/section, a PC based system complete with all required software, comprising of minimum eight nos. of acoustic transreceivers, signal processor, interface unit, PC & colour Inkjet printer (common for one unit) shall be provided. The system shall be able to eliminate the varying high noise environment both in and out of an operating boiler.
- iii) The transit time of each of the associated transmitters/receivers shall be transmitted to the central processing unit (to be located at CER) for storage and analysis through suitable interface device. A temperature profile shall then be determined and displayed by analysing the mean temperature across every transit section using deconvolution technique. The time interval to take a complete cycle of eight transceivers shall be less than one minute.
- iv) The measuring range shall be sufficient to cover the entire regime of boiler operation and shall not be less than 1900°C. The mean temperature and profile temperature accuracy shall be $\pm 2\%$, and $\pm 4\%$ of reading respectively or better. Full colour VDU display and colour printer output shall be provided. The system shall also provide 4-20mA DC output for SG -C&I and BOP- C&I part of DDCMIS.
- v) The transducers shall not be placed directly in the hot gas stream. The system shall be of proven design and it's performance must be proven using similar type of fuel. The components to be located at boiler area shall be able to withstand the stringent environmental condition expected at such locations with operating boiler.

17.3.6 Mill and air heater fire detection system

- i) Adequate number of thermocouples type fire detection system for each mill and air heater shall be provided as a composite and complete units with all required signals and accessories with adequate redundancy.
- ii) The controls & protection required for the mill fire detection system shall be implemented in the SG-C&I and air heater fire detection system shall be implemented in the BOP -C&I Part of DDCMIS using rate-of-rise algorithm as per manufacturer's recommendation.



17.3.7 Flame viewing system

- i) The boiler shall be provided with a flame viewing system. The flame cameras shall be suitable for direct online continuous viewing in the central control room of the coal and oil flame. The numbers of flame cameras to be provided shall be appropriate as per boiler design subject to minimum of two (2) numbers for each boiler.

The facilities/ components of flame camera system shall, as a minimum, consist of 19" high resolution color monitor with facility for zooming and adjustment of iris from the monitor, all necessary remote/local programming tool, proper cooling arrangement (preferably air) and protection against cooling medium failure.

- ii) The cameras and the total system shall be suitable for the fuel being fired considering the ash content of worst coal. The cameras shall be able to withstand the temperature expected in the furnace but shall not be less than 1600⁰C.
- iii) The viewing angle of the camera shall be commensurate with the furnace size, the camera location and the positioning of the burners. The system shall conform to PAL and number of TV lines shall be adequate for a clear image of the furnace.
- iv) The offered flame camera system shall have a record of trouble free performance of minimum one (1) year in a coal-fired boiler of size 500 MW or above where the firing arrangement is similar to the offered boiler.

17.3.8 Separator vessel/ drain level control and monitoring system

The system shall comprise of triple redundant electronics transmitters for separator level and pressure measurements along with all the required control valves & actuators & other accessories. At least eight (8) Nos. thermocouples shall be provided for separator metal temperature measurements. Further, if the separator materials call for stress evaluation of separator, the provision for same shall also be provided.

17.3.9 Acoustic steam leak detection (ASLD) system

- i) PC based Acoustic Steam Leak Detection system shall be provided with Air Borne Sensors including all Signal amplifiers, calibrators, signal processing hardware and software, power supply distribution cables, Instrumentation cables for the entire system including special cables. junction boxes, all erection hardware etc. Minimum thirty (30) number sensors shall be provided. It shall be possible to perform calibration of sensors without disconnecting the sensor.



- ii) Sensor head shall be protected from hot gas, particulate matter, and corrosive elements in the flue gas by suitable protective tube and enclosure which will however not block the sound waves. The probes shall have a minimum life of 20,000 hours of operation. All the parts coming into contact with hot gas shall be designed to withstand the high temperature. Air purging arrangement for sensors including solenoid valves, piping, SS/Cu-tubing, hoses, root valves, isolation valves, air filter regulators shall be provided.
- iii) Display on the PC shall be provided with a mimic display indicating the sensor locations so as to provide a means to physically locate the listening channel and to indicate the alarm condition to show the sensor location which is picking up the present dB alarm level. The system shall continuously monitor the sound level of all the channel and will activate an alarm at a predetermined sound level. The soot blower operation will also be indicated so as to prevent a false alarm during soot blower operation. Suitable means shall also be provided to listen to any channels so as to check and monitor the sound level, especially during an alarm. The ASLD system shall be connected to SG C&I system through hard wiring/ soft link.
- iv) Use of structure borne sensors in place of air borne sensors for some or all of the areas shall be acceptable, if it is the standard practice of the OEM.

17.3.10 Turbine supervisory system (TSS)

- i) The turbine supervisory equipment shall be complete including sensors, transmitters, converters, limit value monitors, measuring and amplifier modules, power supplies etc. with the required accessories including twisted and shielded instrumentation cables, compensating cables, junction boxes etc.
- ii) Following measurements shall be provided also keeping in view the standard and proven practice of the OEM:
 - a) Shaft eccentricity detection.
 - b) Absolute as well as relative shaft vibration measurement in both X & Y direction.
 - c) Differential expansion of rotor and cylinder for HPT, IPT and LPT.
 - d) Overall expansion of HPT and IPT.
 - e) Absolute bearing vibration measurement of each bearing in both X & Y directions.
 - f) Axial shift of the rotor, (three sensors).
 - g) Turbine speed, (three sensors).



- h) Emergency stop and control valve position.
 - i) Main steam and hot reheat steam inlet temperature and pressure.
 - j) Bearing metal and drain oil temperature.
 - k) Turbine casing metal temperature.
 - l) In case of vibration, shaft mounted reference detectors and required supervisory instrument circuitry shall also be provided.
 - m) Any other measurement necessary for safe and reliable operation of the turbine.
- iii) The system shall be provided with suitable hardware and software signal processing and shall be capable of signal distribution and interfacing with other control systems and MMIPIS system.
- iv) For all vibration measurements indicated under (ii) above, a Microprocessor/computer based system shall also be provided to achieve the following functions:
- a) On-line spectrum/harmonic analysis.
 - b) Identification of the exact nature of failure resulting in increase in bearing vibration and direct message on the TFT indicating the exact nature of fault e.g. misalignment, shaft crack, bearing looseness etc. through use of intelligent software packages.
 - c) Storage and comparative analysis of vibrations.
 - d) Generation/ analysis of bode plot/ orbit plot and time waveform/ nyquist plot/ shaft centre line plot/ cascade and water fall plot.
- v) All the vibration parameters as well as turbine supervisory parameters shall also be fed to the turbine control system (TCS) through hardwiring or through suitable link so that all these parameters are suitably displayed on the TG control TFTs. All required I/O cards and other processing modules etc. shall be provided for this purpose.
- vi) Test calibration jigs for site calibration of all sensors of TSS shall be provided.

17.3.11 BFP turbine supervisory instruments

- i) The supervisory equipment/ instruments shall be provided for BFP turbine for detection, indication, recording, monitoring and diagnostics of the following also keeping in view the standard and proven practice of the OEM:
 - a) Shaft eccentricity.
 - b) Axial shift, (with three pickups).



- c) Differential expansion.
 - d) Overall expansion.
 - e) Speed (triple pickups).
 - f) Turbine casing and bearing metal temperature for all bearings.
 - g) Stop valve metal temperature.
 - h) Bearing pedestal vibration (both in horizontal and vertical direction).
 - i) Absolute as well as relative shaft vibration measurement in both X & Y direction.
 - j) Any other measurement necessary for the safe and reliable operation of the turbine.
- ii) Duplex K-type thermocouples/ duplex 100 ohm platinum RTD's shall be provided for the metal temperature and on the thrust bearing faces.
 - iii) Separate and independent hardware/electronics shall be employed for each of the TDBFPs.

17.3.12 HT drives supervisory instruments

Adequate supervisory equipment/ instruments shall be provided for HT drives comprising of ID/FD/PA fans, coal mills, MDBFP, CEPs, CW/ ACW/ DMCW pumps etc. for detection, indication, recording and monitoring of equipment vibrations.

17.4 Plant Performance Analysis, Diagnosis & Optimization (PADO) Software

17.4.1 The plant shall be provided with a PC based on-line plant performance analysis, diagnosis & optimization (PADO) system incorporating complete thermal design model of each unit.

17.4.2 The PADO system perform the following main functions:

- i) Calculate thermal performance status of the plant and efficiency of generation using measured data.
- ii) Calculate all the key system performance indicators at system level such as heat rate, plant and equipment efficiency, generator output and controllable losses.
- iii) Monitor, track and analyze plant emissions such as SO₂, NO_x, CO and CO₂ in real time.
- iv) Monitor and analyze ESP and stack conditions such as temperature, humidity, gas flow rate and opacity.



- v) Facilitate obtaining lowest emission while maintaining combustion efficiency.
- vi) Evaluate system and component performance degradation to detect worn plant equipment.
- vii) Expert system diagnostics using neural and Bayesian belief networks and historical data for quick identification of problem pinpointing down to the component.
- viii) Facilitate obtaining controllable parameter settings to optimize given process or activity at the measured operating condition, using state of the art optimization techniques.
- ix) What if analysis at system and component level.

17.4.3 The PADO system shall also include boiler stress condition analyzer, interactive water and gas chemistry management system and regenerative cycle performance optimization system.

17.5 PLC Based Miscellaneous Control Systems

- i) Independent PLC based Control and Instrumentation system complete with all accessories, auxiliaries and associated equipments and cables etc. shall be provided for the safe, efficient and reliable operation of the standalone plant auxiliaries such as turbine lube oil purification system, central lube oil purification system, condensate polishing plant, on-line tube cleaning system and any other such standalone system. Alternatively, controls of standalone plant auxiliaries can be implemented in Plant DDCMIS also as per standard proven practice of the OEM.
- ii) Each PLC unit shall be provided with two processors (Main processing unit and memories) one for normal operation and other as hot standby. In case of failure of working processor, there shall be an appropriate alarm and simultaneously the hot standby processor shall take over the complete plant operation automatically. The transfer from main processor to standby processor shall be totally bumpless and shall not cause any plant disturbance whatsoever. In the event of both processors failing, the system shall revert to fail safe mode. It shall be possible to keep any of the processors as master and other as standby. The standby processor shall be updated in line with the changes made in working processor.
- iii) The PLC system shall be provided with necessary interface hardware and software for dual fibre optic connectivity & interconnection with station wide LAN for two - way transfer of signals for the purpose of information sharing.



- iv) For PLC system of CPU, two (2) nos. latest version of PC based OWS each with 19" color TFT's and key boards shall be provided for control & monitoring and programming function. One number heavy duty A3 size color printer shall be provided alongwith OWS. Turbine lube oil purification system, central lube oil purification system and any other such standalone system may be provided with panel mounted unit for control & monitoring and programming function as per proven practice of the manufacturer.
- v) Manual intervention shall be possible at any stage of operation. Protection commands shall have priority over manual commands and manual commands shall prevail over auto commands.
- vi) Input Output modules shall be provided for all type of field input signals (4-20 mA, RTD, Thermocouple, non change over/change over type of contact inputs etc.) and outputs from the control system (non change over/change over type of contact, 24/48 VDC output signals for energising interface relays, 4-20 mA output etc.).
- vii) For PLC system, redundant 24 V DC power supply shall be provided. Necessary redundant transformers and redundant chargers with 24 V DC battery back-up shall be provided to derive power supply from 415 V, 3-phase redundant incomers at the input terminals of Power supply cabinets. Each set of PC along with TFT shall be provided with smart type line interactive UPS with battery back up of atleast 30 minute. Alternatively, primary power supply to PLC and PC system can be redundant 230 V AC from smart type line interactive UPS with minimum 30 minutes battery back-up.
- viii) The battery shall be sealed maintenance free Ni-Cd type or Plante type Lead Acid batteries with long life and shall be able to provide a back-up for atleast 30 minute at full load requirement of the complete control system.



SECTION-5

*MISCELLANEOUS
SYSTEMS, PIPING,
VALVES, INSULATION
ETC.*



CHAPTER- 18

POWER CYCLE PIPING, VALVES AND THERMAL INSULATION

18.1 Power Cycle Piping

18.1.1 General

- i) All the piping systems and equipments supplied shall be designed to operate without replacement and with normal maintenance for a plant service life of 25 years and shall withstand the operating parameter fluctuations and cycling which can be normally expected during this period.
- ii) The design, engineering, erection, testing, etc. of the complete piping systems shall be to the requirements of power piping code ANSI B 31.1. In addition to this, requirements as laid down in Indian Boiler Regulations (latest edition) shall also be met completely.

18.1.2 Pipe sizing

- i) Inside diameters of piping shall first be calculated for the flow requirement of various systems based on velocity limits listed below:
 - a) Main steam, CRH & HRH : 76m/s
 - b) Auxiliary steam : 50 m/s
 - c) Feed water suction : 2.0-3.0 m/s
 - d) Feed water discharge : 4.0-6.0 m/s
 - e) HP/LP bypass upstream : 100 m/s
 - f) HP/LP bypass downstream : 125 m/s
 - g) Extraction steam (superheated) : 60 m/s
 - h) Extraction steam (saturated) : 30 m/s
 - i) Condensate suction : 1.5 m/s
 - j) Condensate discharge : 3.0-5.0 m/s
 - k) Other pipings : As per good engg. practice



- ii) Pressure drop in reheat steam circuit (cold reheat, hot reheat line & reheater) should not exceed 10 % of HP turbine exhaust pressure.
- iii) Pipes shall be sized for the worst operating conditions (i.e. maximum flow, temperature and pressure values). In case of BFP suction piping, transient analysis shall be carried out for optimum sizing of the system in order to establish the pipe inside diameter for minimum pressure drop in system to match with the pump NPSH requirement under worst operating conditions.
- iv) The design pressure for BFP discharge piping up to and including downstream valve at feed regulating station (FRS) shall be selected such that the minimum calculated thickness for various pipes at design temperature is sufficient for the following conditions, considering allowable stresses as per ASME B31.1:
 - a) Discharge pressure corresponding to turbine driven BFP trip speed at shut off head condition, if TDBFP characteristics is governing for calculation of boiler feed discharge piping design pressure.
 - b) Discharge pressure corresponding to motor driven BFP trip speed (frequency 51.5Hz) at shut off head condition if MDBFP characteristics is governing for calculation of boiler feed discharge piping design pressure.
- v) With feed regulating station (FRS) located at upstream of HP heaters and no isolating valve provided at inlet of economiser, the design pressure of boiler feed discharge piping at downstream of FRS shall be worked out corresponding to design pressure of the boiler. This shall be for HP heaters provided with spring loaded relief valve(s) or having provision of media operated three way valves at inlet/ outlet of HP heater(s) as per approval of IBR so as to prevent BFP shut off pressure from being communicated to downstream piping system and HP heaters.
- vi) The design pressure and temperature, down-stream of any pressure reducing valve upto and including the first block valve shall be the same as that at up-stream of pressure reducing valve. If a pressure relief valve is provided in the down stream of PRV, the downstream piping shall be designed to a lower pressure as per set pressure of the relief valve.

The piping at down stream of de-superheater shall be designed for spray failure condition. The length of piping system considered for spray failure condition shall not be less than the length required for proper spray mixing as recommended by de-superheater supplier.



18.1.3 Material selection

The material used for power cycle piping shall be equal to or better than the following unless specified otherwise:

Design metal temperature		Material
i)	Upto & including 400 ⁰ C	Carbon steel to ASME SA-106 Gr. B/C or SA 210 Gr. C or equivalent.
ii)	Upto & including 550 ⁰ C	Alloy steel to ASME SA-335: P-11, P-12, P-22, P-91 or equivalent.
iii)	Upto & including 605 ⁰ C	Alloy steel ASME SA-335/213:P-91, P-92 or equivalent.
iv)	Above 605 ⁰ C	Austenitic stainless steel, P-92, Super 304H, TP347H or equivalent.

18.1.4 Pipe wall thickness

- i) Pipe wall thickness calculation shall be made on the basis of procedure and formula given in ASME B 31.1. Stress values of piping material for calculation shall be selected from tables given in ASME B 31.1. Thickness, thus calculated shall be checked as per IBR formula (where applicable) and the more stringent of the two shall then be selected. In any case the thickness selected shall not be less than the standard thickness specified in ANSI B 36.10. In such cases where thickness calculated does not fall in the standard range of thickness as given in ANSI B 36.10, ID/OD controlled pipes as per ASA-530 shall also be acceptable.
- ii) The selected pipe thickness shall not be less than Sch.80 for alloy steel & carbon steel pipes of sizes 50 NB & below. The selected thickness for SS pipes shall not be less than Sch.40S of ANSI B36.19.
- iii) For the piping systems likely to be subjected to two phase flow, i.e. down stream of control valves on heater drain lines etc. and for the length of piping which is required for the proper mixing of spray water at downstream of de-superheater, the selected thickness shall not be less than Sch.40 for pipe sizes above 50 NB but below 300 NB and Sch. STD for pipe sizes 300 NB and above.
- iv) To account for losses due to corrosion, erosion etc. during the plant service life, an allowance of 1.6 mm/0.75 mm shall be considered in the minimum wall thickness calculation of pipes as per ASME B31.1/IBR respectively.

18.1.5 Layout

- i) All high points in piping system shall be provided with vents. All low points shall be provided with drains. Provisions of drains on steam piping shall be as per ASME code TDP-1. Drain lines shall be adequately sized so as to clear condensate in the line and prevent water hammer and damage to turbine due to water induction.



- ii) All piping shall be sloped towards the system low point such that slope is maintained in both hot and cold condition.
- iii) The pipe routing shall be such that a clear head room of not less than 2.2 m above the walkways/ working area is available.

18.1.6 Stress/ dynamic analysis

- i) Flexibility and stress analysis for various piping systems shall be carried out by the contractor as per the requirement of ANSI B 31.1. Analysis results shall satisfy the following:
 - a) Calculated stresses in the piping system shall be within the allowable limits stipulated in ASME B 31.1 as well as IBR for piping under the purview of IBR.
 - b) Calculated forces and moments on equipment nozzles/TP shall not be more than the allowable loading provided by equipment manufacturer(s). Flexibility analysis shall also calculate the deflections in all directions (translational and rotational) to enable design and selection of hanger/support system.
 - c) Besides the flexibility analysis, steam hammer analysis/ dynamic analysis shall also to be performed wherever required to study the effects of fast closure of steam admission valves and safety valve blowing. Requirements of additional restraints/ snubbers to take care of these effects shall be established, and such restraints/ snubbers shall be provided. The effects of seismic and wind loads and adequate support to take care of the same shall be provided.
- ii) Cold pulling shall not be used and piping systems shall be so designed that there will be no requirement of cold pull for meeting allowable reaction/ stress values.

18.1.7 Specifications for piping and fittings

	Alloy Steel	Carbon Steel
i) <i>Pipes</i>		
a) Material	X20 Cr. Mo V 121 to DIN 17175 OR ASTM A335 Gr.P91 OR ASTM A335 Gr.P22 OR ASTM A335 Gr.P11 OR ASTM A691 2-1/4 Cr. Class 22 (See Note below)	ASTM 106 Gr. B/ Gr. C (ASTM 106 Gr. C for BFD and CRH design parameters with ASTM A335 P36/ WB 36 as alternate material for BFD design parameters) ASTM A 672 Gr. B60 CLASS-12/22 (See Note below)
b) Construction	Seamless (See Note below)	



ii) Fittings		
a) Material for 200 NB & above	X20 Cr. Mo V 121 to DIN 17175 OR ASTM A234 Gr.WP91 OR ASTM A234 Gr.WP22 OR ASTM A234 Gr.WP11	ASTM A 234 Gr. WPB for ASTM 106 Gr. B piping ASTM A 234 Gr. WPC for ASTM 106 Gr. C piping ASTM A335 P36/ WB 36 for ASTM A335 P36/ WB 36 piping
b) Material for 65 NB to <200 NB	ASTM A234 Gr.WP91 OR ASTM A234 Gr.WP22 OR ASTM A234 Gr.WP11	
c) Material for 50 NB and Below	ASTM A182 Gr. F91 OR ASTM A182 Gr. F22 OR ASTM A182 Gr. F11 (See note below)	ASTM A105
d) Basic standards	ANSI B 36.10, ANSI B16.9, ANSI B16.11, ANSI B 16.25, ANSI B 16.28 & DIN 17175	ANSI B 36.10, ANSI B16.9, ANSI B16.11, ANSI B 16.25, ANSI B 16.28 & EN 1.6368
e) Construction	Seamless (Forged for 50 NB & below)	
f) Rating/ wall thickness	To match with that of pipe	
iii) Welding		
Backing rings	Not permitted	
iv) Material Analysis		
Mandatory requirements	All tests, as given in respective material code (other than supplementary requirements), shall be carried out as minimum. This includes the tests wherein it is specified in the respective material code that “the test is to be carried out when specified by the purchaser” or any such indication, in the code.	
v) Hydrostatic Test Pressure		
a) Piping system under IBR purview:		
1. At shop	All piping including fabricated piping shall be hydro tested at 1.5 times the design pressure subject to regulation 374 of IBR. However, non-destructive testing in lieu of hydro test is also acceptable subject to regulation 343 (3) of IBR.	
2. After erection	All piping systems shall be hydro tested at 1.5 times the design pressure subject to regulation of 374 IBR. However, for such systems where it is practically not possible to do hydro tests, the tests as called for in ANSI B31.1& IBR in lieu of hydro test shall also be acceptable.	



b) Non-IBR piping systems:	
1. At shop	All piping including fabricated piping shall be hydro tested at 1.5 times the design pressure. However, non-destructive testing in lieu of hydro test is also acceptable subject to regulation 343 (3) of IBR.
2. After erection	All piping systems shall be hydro tested at 1.5 times the design pressure. However, for such systems where it is practically not possible to do hydro tests, the tests as called for in ANSI B31.1 & IBR in lieu of hydro test shall also be acceptable.

Notes:

1. Material X20 or P91 is applicable for Main Steam and HP Bypass line upto HPBP valve. However, for pipes sizes 150 NB & below in these piping systems, A335 P22 shall also be acceptable.
2. Material P22 or P91 are applicable for Hot Reheat, and LP bypass.
3. In case design temperature is above 550⁰C and upto 605⁰C, then P91 or equivalent material only shall be applicable (for 1 & 2 above).
4. EFW pipes as per ASTM A 691 2-1/4 Cr. Class 22 are acceptable for alloy steel piping of size 550 NB & above if the design pressure and design temperature are such that it calls for ASME 300 class or below.
5. EFW Pipes as per A 672 Gr. B60, Class 12/22 are acceptable for carbon steel piping of size 550 NB & above if the design pressure and design temperature are such that it calls for ASME 150 class or below.
6. The fitting for ASTM A672 piping shall correspond to ASTM A 234 with Grade corresponding to the pipe material. Welded construction fittings are also acceptable with A672 piping. However, all requirements as per ASME B31.1 including the requirements given in mandatory appendix-D, IBR & respective material code shall be fully complied with, in respect of welded fittings.
7. Pipe material for CRH piping from HPT exhaust nozzle up to CRH NRV shall be alloy steel to ASTM A335 Gr.P22/ Gr.P11. Fittings shall also be corresponding to ASTM A 234 Gr. WP22/ Gr.WP11.
8. Pipe material for HP Bypass and LP Bypass downstream piping upto the mixing length as per recommendation of valve manufacturer shall be of Alloy steel to ASTM A335 P11/ P22. Fittings shall also be corresponding to ASTM A 234 Gr. WP11/ WP22.



9. Material P-22 is applicable for piping with temperature $> 510^{\circ}\text{C}$ and upto 550°C and P11 is applicable for all other alloy steel piping below 510°C .
10. Materials for fittings, specialties and valves shall be corresponding to piping material or equivalent.

18.1.8 Specific requirements

- i) Manufacturing tolerances on pipe diameter (for both ID and OD controlled pipes) and thickness shall be as per ASTM A-530/ A999M, as applicable.
- ii) Bend thinning allowance shall be provided for all bends as per the recommendations of ANSI B 31.1.
- iii) Maximum carbon content for ASTM A 106 Gr. B or A- 105 shall be limited to 0.30% and for ASTM A 106 Gr. C, it shall be limited to 0.35%.
- iv) All drains and vent lines in piping system with design pressure 40 kg/cm² and above shall have two valves in series.
- v) Wherever mitered bends are used, the thickness of pipe from which they are fabricated shall conform to the requirements of IBR Regulations 361 (C). The angle between axes of adjoining pipe sections shall not exceed 22.5 degree.
- vi) Piping system fabrication shall be in accordance with the requirement of ANSI B 31.1. However for system under purview of IBR, the requirements of IBR shall also be complied with.
- vii) Where welded pipe and fittings are used the longitudinal weld seams of adjoining sections shall be staggered by 90 degree.

18.1.9 Valves

- i) All valves shall be full port and shall meet the requirements of ASME B 16.34. The class of the valves shall be compatible to the service requirements. All materials that are bent, forged or formed shall be subject to heat treatment after the forming operations as required by the original material specification. For alloy steel materials the preferred heat treatment process is full annealing.
- ii) Valves of size 65 NB and above shall have butt welded ends as per ANSI B16.25 and valves 50 NB and below shall have socket weld ends as per ANSI B16.11. Rubber lined valves shall have flanged ends as per ANSI B16.5.



- iii) All gate and globe valves shall be with outside screw and yoke with rising stem. Gate valves below 100 NB shall be solid wedge/flexible wedge type. Valves of class 150/ 300 and size 100 NB and above shall be of flexible wedge type. However, for sizes 100 mm NB and above for temperatures above 300⁰C, parallel slide valves are also acceptable.
- iv) All globe valves shall be capable of being closed against the design pressure. Where globe valve has been specified for regulation purpose, the disc shall be tapered plug type and suitable for controlling throughout its lift.
- v) All gate and globe valves shall have bonnet-back seating arrangement to facilitate easy replacement of packing with the valves in service.
- vi) All gate, globe and check valves shall be designed for reconditioning of seating surfaces and replacement of stem and disc without removing the valve body from the line.
- vii) Minimum differential hardness between seat and other disc material shall be 50 HB in case of 13% chrome hardened with heat treatment of steel.
- viii) For all globe and check valves, the direction of flow shall be clearly stamped on the body of the valve.
- ix) Locking arrangement, where provided shall be of non-detachable type.
- x) Integrated bypass valves:
 - a) The requirement of integral bypass valves shall be worked out, as per process requirement.
 - b) Integral bypass shall be motor operated if main valve is motor operated.
 - c) Bypass pipe shall be of seamless construction and thickness corresponding to minimum of schedule 80 and shall be of the same material class as the main pipe.
- xi) For valves of size 65 NB and above in vacuum service, water gland sealing arrangement shall be provided. Valves of size 50 NB and below shall have extra, deep gland packing without requiring water gland sealing.

18.1.10 Hangers and supports

- i) All hangers and supports shall be so erected that they are preferably vertical when the piping is in hot condition (rated parameters). However, in piping system connected to the turbine/turbine valve nozzles it may be required to erect the hangers/supports vertical in the



cold condition or as per the recommendation of TG supplier to ensure that there is no transfer of undesired pipe weight/ load on the turbine valves/nozzles.

- ii) All pipes hangers and supports shall be designed to carry the weight of the piping, fitting, thermal insulation, self weight of the hanger assembly and medium transported or test medium whichever is heavier. In addition, all rigid rod hangers and variable spring shall be designed to carry the operation load in hot condition.
- iii) Design and Manufacture of hangers and supports shall conform to ANSI B 31.1, MSS-SP-58, MSS-SP-89.

18.1.11 **Metallic expansion joints**

- i) The expansion joints shall be of metallic multi-bellows construction and shall be used to reduce the reactions (forces and moments) at the connected equipment terminals due to thermal expansion/contraction and/or vibration of connected equipment and piping.
- ii) Expansion joints shall comply with the currently applicable requirement of EJMA, Boiler and Pressure Vessel Code Section III, ANSI B-31.1 and all statutes, regulations and safety codes.

18.1.12 **Chemical cleaning of piping systems and equipments**

- i) The following piping system shall be cleaned chemically:
 - a) Boiler feed discharge piping
 - b) Heater drains piping
 - c) Main condensate piping
 - d) Extraction steam piping
- ii) The following equipments which form a part of the above system shall also be included in the cleaning operation as per OEM's proven practice:
 - a) HP Heaters
 - b) LP Heaters
 - c) Deaerator
 - d) Gland steam condenser
 - e) Drain cooler
- iii) Before introducing chemicals, all the piping systems and equipment listed above shall be water flushed. Water flushing will be followed by alkaline cleaning, acid cleaning and passivation or by EDTA (Ethylene Diamene Tetra Acid) and passivation.
- iv) Strict safety precautions shall be exercised at all times during the chemical cleaning and during storage and handling of the chemicals. Protective clothing, apparatus and equipment alongwith necessary first aid kits as required shall be envisaged for handling the chemical and for carrying out the cleaning operation.



18.1.13 Steam blowing of piping systems

- i) The following piping systems shall be cleaned through steam blowing operation:
 - a) Main steam, HRH, CRH, HP bypass & LP bypass piping.
 - b) Auxiliary steam piping including TG gland sealing lines.
 - c) Steam lines feeding turbines of boiler feed pumps.
- ii) Steam blowing shall be carried out for removal of particles (rust, scales, weld splatter etc.) from various piping systems to avoid damage to turbine bladings. Cleanliness of system shall be checked by means of test plates made of steel, which will be installed in the centre line of the piping system.
- iii) Cleaning shall be achieved by steam purging i.e. by blowing of steam through the piping such that the momentum of flow is greater than that of steam flow during normal operation of unit (at TMCR). The disturbance factor during steam blowing (ratio of momentum of flow during purge to that during TMCR) shall be more than 1.4.

18.2 Control Valves

18.2.1 General requirements

- i) The control valves shall comply with the latest applicable requirements of code for pressure piping ANSI B 31.1, the ASME Boiler & pressure vessel code, Indian Boiler Regulation (IBR), ISA as well as in accordance with all applicable requirements of the Federal Occupational Safety and Health Standards, USA or acceptable equal standards.
- ii) The control valve sizing shall be suitable for obtaining rated flow conditions with valve opening at approximately 80% of total valve stem travel and minimum flow conditions with valve stem travel not less than 10% of total valve stem travel. All the valves shall be capable of handling at least 120% of the required rated flow. Further, the valve stem travel range from minimum flow condition to rated flow condition shall not be less than 50% of the total valve stem travel. The sizing shall be in accordance with the latest edition of ISA on control valves. The valves port outlet velocity shall not exceed 8 m/sec for liquid services, 150 m/sec. for steam services and 50% of sonic velocity for flashing services.
- iii) Valve body rating shall meet the process pressure and temperature requirement as per ANSI B16.34.
- iv) All control valves shall have leakage rate as per leakage Class-IV.



- v) For cavitation service, only valve with anti cavitation trim shall be provided. Applications like CEP minimum recirculation valve shall have anti-cavitation trim with tight shut-off. The deaerator level control valve shall have characterized trim cages to have a cavitation protection at minimum flow as well as good rangeability.

18.3 Thermal Insulation

18.3.1 General requirements

- i) Thermal insulation shall be provided mainly for conservation of heat and maintenance of temperature as per design cycle and personnel protection.
- ii) Insulation alongwith aluminum cladding shall be provided for all the equipments/surfaces (excluding coal pulverisers) having skin temperature more than 60⁰C.
- iii) For the piping and the equipment with surface operating temperature of 60⁰C and above, the personnel protection insulation shall be applied such that the temperature of protective cladding is below 60⁰C.
- iv) An insulation thickness schedule shall be prepared covering both the cases of heat conservation and personnel protection based on the following design data:
 - a) Design ambient temperature : 40⁰C
 - b) Maximum cladding temperature : 60⁰C
 - c) Wind speed : 0.25m/s
 - d) Emissivity of cladding : 0.2
 - e) Thermal conductivity : As per relevant IS
 - f) The minimum acceptable insulation thickness : 1. 75 mm for Boiler & TG
2. 70 mm for ESP surfaces
3. 25 mm for other surfaces
 - g) Pipe/equipment wall temperature : Fluid design temperature
- v) The insulation thickness to be provided shall be calculated as per ASTM C-680 or BS- EN-ISO 12241 subject to minimum thickness values as mentioned above.
- vi) The material and application of insulation material, protective cladding, wire mesh etc. shall conform to the latest edition of the following standards/ codes:



a)	IS 280	Mild steel wires for general engineering purposes.
b)	IS 3144	Methods of test for mineral wool insulation materials.
c)	IS 3677	Unbonded rock and slag wool for thermal insulation.
d)	IS 5696	Loose mineral wool.
e)	IS 8183	Lightly bonded mineral wool for thermal insulation.
f)	IS 9428	Pre-formed calcium silicate insulation.
g)	IS 9742	Sprayed mineral wool thermal insulation.
h)	IS 9842	Preformed fibrous pipe insulation.
i)	IS 4164	Code of practice for thermal insulation on cold surfaces.
j)	IS 15402	Ceramic fibre blanket insulation.
k)	IS 737	Wrought aluminum and aluminum alloy sheet and strip for general engineering purposes.
l)	ASTM C 892	Standard specification for high-temperature fiber blanket thermal insulation.
m)	ASTM B 209	Standard specification for aluminum and aluminum- alloy sheet and plate.

18.3.2 Technical requirements

- i) All insulating materials, accessories and protective covering shall be non-sulphurous, incombustible, low chloride content, chemically rot proof, non-hygroscopic and shall be guaranteed to withstand continuously and without deterioration the maximum temperature to which they will be subjected under the specified conditions.
- ii) Insulation materials containing asbestos in any form shall not be used.
- iii) Insulation mattress/section shall be in thickness of 25, 40, 50 and 75 mm. Insulation of higher thickness shall be made up in multiple layers using these mattress/slabs. If required, the mattress/slabs in increment of 5mm thickness may be used to achieve the required thickness of insulation.
- iv) Special fire protection measures shall be taken for the steam lines running in the immediate vicinity of oil lines. The sheet metal jacketing shall be made oil proof by inserting self-adhesive flexible tapes.
- v) Rock wool insulation mattress shall be of long fibered rock processed into fibrous form bonded with a binder. No kind of slag wool inclusion is acceptable.



- vi) The thermal insulation for the turbine casing shall consist of sprayed insulation produced by projecting specially prepared mineral wool along with a fine liquid spray. This shall be covered with prefabricated 'blanket' type insulation. Voids around the blankets should be avoided. However, unavoidable voids shall be filled with loose mineral wool.

18.3.3 Materials of insulation

i) *Insulation*

Type	Type # 1	Type # 2	Type # 3	Type # 4	Type #5
Material	Lightly resin bonded mineral (rock) wool	Resin bonded mineral (rock) wool pre-formed pipe sections/ blocks	Calcium silicate pre-formed pipe sections/ blocks	Rock wool for spray insulation	Ceramic fibre blankets/ blocks
Apparent density	100 kg/m ³ for temp. 60-400 ⁰ C and 150kg/m ³ for above 400 ⁰ C.	100-150 kg/m ³	200-25-kg/m ³	200-250 kg/m ³	128 kg/m ³
Material standard & testing code	IS:8183	IS:9842	IS:9428	IS:9742	IS:15402
Applicable service	Piping system & equipment with operating temp. range of 60-650 ⁰ C.	Piping system of 350 NB and below with temp. range of 60-400 ⁰ C.	Piping system & equipment with operating temp. range of 400-650 ⁰ C.	Steam turbine & valves with operating temp. range of 400-650 ⁰ C.	Steam turbine, boiler surfaces & valves with operating temp. range of 400-650 ⁰ C.

ii) *Sheathing/ Cladding Material*

Sheathing/ cladding material for all insulated surfaces. equipment, piping etc. confirming to ASTM B 209-1060 temper H-14 or IS-737 Gr.19000/H2 shall be provided as follows:

- a) For dia. of insulated surfaces : 0.914 mm (20 SWG)
of 450 mm & above and for flat surfaces
- b) For dia of insulated surfaces : 0.71 mm (22 SWG)
less than 450 mm



- c) For steam generator outer casing : 1.219 mm (18 SWG) ribbed Aluminum
- d) For ESP : 0.71 mm (22 SWG) ribbed Aluminum

iii) *Binding and Lacing Wires*

- a) For temperature upto 400⁰C : 20 SWG galvanised steel
- b) For temperature above 400⁰C : 20 SWG stainless steel

iv) *Straps and Bands*

- a) For temperature upto 400⁰C : Galvanised steel
- b) For temperature above 400⁰C : Stainless steel

Bands shall be 20 mm wide and 0.6 mm thick.

v) *Hexagonal Wire Mesh*

- a) Upto 400⁰C : 22 SWG, 10 to 13 mm aperture galvanised steel
- b) Above 400⁰C : 22 SWG, 10 to 13 mm aperture stainless steel

18.4 Refractories

- i) The refractory material shall comply with relevant Indian Standards. The refractory selected shall ensure perfect sealing, and shall have good thermal cycling properties allowing quick start-up/shut down of steam generators.
- ii) The refractory material shall:
 - a) have high bulk density and minimum moisture content.
 - b) be capable of withstanding service temperature of 1700⁰C.
 - c) be resistant to slagging products due to coal, and to impurities of oil like V₂O₅, Fe₂O₃, K₂O etc. and to erosion due to fly ash.
 - d) be chemically inactive towards alkalies, iron, silica etc.
 - e) shall pose no health hazard to working personnel, and shall not have any explosive properties.
 - f) have sufficient strength to withstand forces generated in boiler, without any rupture or damage.



CHAPTER - 19

STEAM TURBINE HP-LP BYPASS SYSTEM

19.1 Purpose

The HP and LP turbine bypass system is envisaged to be used for the following functions:

- i) To enable boiler and turbine to be operated independent of each other during start-up and shutdown.
- ii) To enable in quick reloading of the unit following a turbine trip.
- iii) To quickly open to relieve the system from high steam pressure in the event of generator breaker opening/ turbine tripping as well as during large load throw-off.
- iv) To reduce starting and loading time of steam generator.
- v) For house load operations.

19.2 General Requirements

- 19.2.1 A HP bypass system shall be provided between MS and CRH and shall have aggregate capacity not less than 60% of the main steam flow at BMCR condition considering main steam parameters at the upstream of valves & CRH steam parameters corresponding to 60% TMCR condition on the downstream side. The HP bypass system shall have minimum 2x50% capacity valves. In addition the aggregate capacity of HP Bypass valves shall be adequate to evacuate the required minimum steam flow from the boiler under various start- up conditions (viz. cold/ warm/ hot start ups).
- 19.2.2 LP bypass shall be provided between HRH and condenser and shall be designed to condition the incoming steam from re-heater corresponding to parameters resulting from operation of HP bypass as stated above, to parameters matching with those of LP Turbine exhaust steam. The valve capacity shall be commensurate with that of HP bypass system plus the spray water used in HP bypass. Number of LP Bypass valves shall be as per manufacturer's standard practice subjected to a minimum of two (2) numbers.
- 19.2.3 Seat tightness of the HP and LP bypass valves shall be equivalent to leakage Class V conforming to ANSI/FCI 70-2.
- 19.2.4 HP bypass station spray water requirement shall be provided from Boiler feed pumps discharge & LP bypass spray water requirement shall be provided from condensate extraction pump discharge.



- 19.2.5 HP bypass shall be designed to accept continuous spray water at temperature corresponding to all HP heaters out of service and deaerator pegged at pressure 3.5 ata or as per OEM practice.
- 19.2.6 For LP bypass system the de-superheating may be done outside the valve body with spray water tapped from condensate pump discharge.
- 19.2.7 All valves (both in steam and spray water service) shall be electro hydraulically operated. Separate or common oil system with 100% redundant pumps, motors, accumulators and control cubicles etc. shall be provided for HP and LP bypass systems. , For LP bypass system, the control fluid supply can be taken from the steam turbine control fluid system also based on OEM's standard practice.
- 19.2.8 Warming up arrangement shall be provided for HP/LP bypass valves and associated piping.
- 19.2.9 The system shall be suitable for operations under sliding pressure mode to enable short start-up time. It shall also be capable of operation in parallel with turbine with all feed water heaters in service.
- 19.2.10 The boiler operation should not be affected in the event of loss of load on the turbine, and the HP LP bypass systems shall be capable of disposing off the steam produced in the boiler automatically by providing a quick opening device. The full stroking time of valve under quick action shall be within 2 to 3 seconds.
- 19.2.11 HP- LP bypass system shall facilitate hot and warm restart of the unit following a trip from full load, part loads, controlled shutdown and cold start up following a long shutdown.
- 19.3** Steam Turbine trip will call for boiler operation in HP/LP bypass mode. The economizer shall be suitably designed to take a thermal shock of sudden change of feed water temperature from rated value(s) to about 140°C during HP/LP bypass mode operation. The superheater and reheater outlet temperature shall be maintained during HP/LP bypass operation.



CHAPTER- 20

AUXILIARY STEAM PRESSURE REDUCING & DESUPERHEATING SYSTEM

20.1 General

To meet the continuous and startup auxiliary steam requirements of the unit(s), two auxiliary pressure reducing and desuperheating stations, one high capacity PRDS taking tap off from main steam (MS) or intermediate stage of superheaters as per proven practice of OEM and other low capacity PRDS taking tap off from cold reheat (CRH) lines shall be provided. A high temperature unit header by taking steam from both the above PRDS and also a low temperature unit header by taking steam from the high temperature unit header through a desuperheater shall be provided. The respective high temperature and low temperature auxiliary steam headers of individual units shall be interconnected. Provision shall be kept for interconnection of respective high and low temperature station headers with corresponding header(s) of future unit(s). Output steam of the auxiliary boiler (if provided) shall be connected to the low/ high temperature station header.

As per manufacturer's standard and proven practice, each unit can be provided with only high temperature auxiliary steam header with auxiliary steam requirement at lower parameters to be met from this header using suitable PRDS for individual application.

If steam for the Steam Generator unit auxiliaries is required at pressure/temperature other than that of the auxiliary steam headers, suitable arrangements shall be made in design of the Steam Generator to meet such requirements.

In addition to the above, a pressure reduction station shall also be provided to supply steam at required parameters for fuel oil heating and air conditioning plant (if required). The pressure reducing station shall draw steam from a tap off provided on low temperature auxiliary steam station header.

20.2 High capacity PRDS shall be sized for auxiliary steam requirement of about 150 TPH and shall be generally sized to cater to the auxiliary steam requirements for following:

- i) Startup requirement of the unit.
- ii) Continuous and intermittent requirement of the unit.
- iii) Startup requirement of other unit.
- iv) As standby to low capacity PRDS station.



- 20.3** Low capacity PRDS shall be sized for auxiliary steam requirement of about 20 TPH including for requirement of fuel oil heating and air conditioning plant (if required) and shall supply steam for normal continuous requirements of its own unit.
- 20.4** Sharing of Load requirement between high capacity station header and low capacity station header shall be possible in case low capacity PRDS is unable to meet Auxiliary steam requirement on its own. The change over from high capacity PRDS to low capacity PRDS & vice versa shall be automatic.



CHAPTER- 21

EQUIPMENT COOLING WATER (ECW) SYSTEM

21.1 General

Closed circuit type ECW system shall be provided with demineralised (DM) water in the primary circuit and water tapped off from CW system upstream of condenser in the secondary circuit. ECW system shall be provided unit-wise and shall cater to cooling water requirements of TG and its auxiliaries as well as Steam Generator auxiliaries. Primary cooling circuits for auxiliaries of TG and SG packages shall be independent. The secondary cooling water circuit shall, however, be common for both the primary cooling systems.

21.2 System Requirements

- 21.2.1 For primary circuit of TG auxiliaries of each unit, a set of demineralised cooling water (DMCW) pumps of 3x50% capacity shall discharge the cooling water through 3x50% capacity plate heat exchangers (PHE). For SG auxiliaries of each unit, 2x100% capacity DMCW pumps and 2x100 % capacity plate heat exchangers shall be provided.
- 21.2.2 The outlet header from plate heat exchangers shall be suitably branched off to supply the cooling water to the various auxiliary coolers. Outlet from the auxiliary coolers shall be connected back into a common return header and led back to the suction of DMCW pumps to complete the closed loop primary cooling circuit.
- 21.2.3 For both the primary cooling circuits of each unit, an overhead tank of minimum effective capacity of 10 m³ corresponds to 60% of the tank height shall be provided with level control facility. The overhead tank shall serve the following:
- i) For normal make-up to closed loop cycles.
 - ii) To meet expansion of closed cycle water due to temperature fluctuations and to control other transients.
 - iii) For adequate Net Positive Suction Head (NPSH) for DMCW pumps.
 - iv) Emergency water supply to critical coolers in case of power failure.
- 21.2.4 The pH of DM water in the closed loops shall be continuously monitored and controlled at around 9.5. The pH shall be controlled by dosing sodium hydroxide or ammonia in DM water overhead tank and primary side piping for TG and SG auxiliaries.



- 21.2.5 The common secondary circulating water system shall operate in parallel to the condenser and shall receive water through a tapping on the CW inlet line to the main condenser. Pressure of this water shall be further boosted by a set of 3x50% or 2x100% capacity secondary cooling water (SCW) pumps and fed through the plate heat exchangers back to the CW discharge line of the main condenser. Alternatively, separate set of pumps basis may be provided in the CW pump house to supply secondary cooling water for PHEs of each unit.
- 21.2.6 To prevent fouling on the secondary circulating water side of the PHE, 2x100% capacity self cleaning type filters shall be provided on the circulating water inlet header to the PHE. The filter shall be provided with an automatic back-wash arrangement to facilitate cleaning of the choked filter while the pumps are in operation. Backwashing shall be actuated and controlled either according to differential pressure and/ or by timer. Backwash shall be collected in a sump and 2x100% capacity sump pumps of adequate capacity shall be provided for disposal of collected backwash water.
- 21.2.7 Normal/ emergency make up to the overhead tank shall be supplied through motorised valve(s) interlocked to open/ close automatically with level in the tank.
- 21.2.8 A control valve shall be provided to maintain a constant pressure differential between the main supply and return headers of DM water. The valve shall bypass flow to maintain a constant return header pressure to compensate for fluctuations in coolant flow to the process heat exchangers due to modulating control valves on the process coolers or if any cooler goes out of service in DM circuit.

21.3 Design Requirements

21.3.1 Pumps (primary side & secondary side)

- i) The pumps shall be of horizontal centrifugal type provided with closed type impeller and axial split casing.
- ii) The pumps shall be designed as per requirements of Hydraulic Institute Standards (HIS), USA.
- iii) The pumps shall have stable head- capacity characteristic with head rising continuously towards the shut off. The shut off head of the pump shall be in the range 115-130% of the rated head. The power characteristics shall be of non-overloading type.
- iv) The pumps shall be suitable for continuous operation and shall operate satisfactorily in the range 40% to 120% of the rated flow.
- v) The pump shall be driven by constant speed squirrel cage induction motor with speed not exceeding 1500 rpm (synchronous).



- vi) The materials of construction of primary and secondary cooling water pumps shall be as given below or equivalent:

Description	Primary DM cooling water pumps	Secondary cooling water pumps	
		For fresh water	For sea water
a) Casing	ASTM-A-351 CF8M	2.5% Ni CI, IS 210 Gr FG 260	18% Ni CI ASTM A 439 type D ₂ / ASTM A 351 Gr CF8M
b) Impeller	ASTM-A-351 CF8M	Bronze to IS 318 Gr. I/II or SS 316	ASTM A 351 Gr CF8M/ Duplex SS
c) Shaft	SS 316	EN-8 (BS-970)	AISI 420
d) Shaft sleeve	SS 410	SS 410	Duplex SS
e) Impeller wearing rings	SS 316	High leaded bronze to IS-318 Gr. V / SS 316 in case of SS impeller	Hardened Duplex SS/ ASTM A 351 Gr CF8M/ SS 316 L

21.3.2 Heat exchangers

- i) The heat exchangers shall be of plate type with single pass design.
- ii) The design pressure shall be equal to DMCW pump shut off pressure at 51.5Hz with maximum suction pressure.
- iii) The plates shall be of SS-316. For sea water application, titanium plates shall be used.
- iv) The thickness of plate shall not be less than 0.6 mm. The thickness of pressure and frame plates shall be as per ASME Sec. VIII Div. I.
- v) All the plates shall be tested by light box/ vacuum/ air chamber test as per manufacturer's standard practice. At least 10% plates shall also be randomly tested by dye-penetration test.
- vi) The corrosion allowance for carbon steel parts of the heat exchanger which are in direct contact with water such as support plates, nozzles shall be 1.6 mm (minimum).
- vii) Double sealing arrangement shall be provided for sealing at outer edges and around ports to avoid intermixing of fluids.
- viii) The frame of each heat exchanger plate shall have about 25% extra capacity i.e. the frame shall be able to accommodate about 25% extra plates.



21.3.3 Butterfly valves

- i) The butterfly valves shall be designed as per AWWA C-504 or BS 5155 and tested as per AWWA C-504 standard.
- ii) The design pressure of valves shall be equal to pump shut off pressure at 51.5Hz with maximum suction pressure.
- iii) The materials of construction of valves shall be as given below or equivalent:

Description	Primary side valves	Secondary side valves*
a) Body and disc	2% Ni- CI	CI to IS 210 FG-260/ ASTM A216-CLB or fabricated steel as per ASTM A- 515 Gr 60/ 80/ IS 2062/ IS 2002
b) Shaft	SS 410	AISI 410
c) Retaining segment	SS 316	SS 316
d) Internal hardware	SS 316	SS 316
e) Seal	Buna- N	Buna- N

* Materials indicated are for fresh water application. In case of sea water, materials of construction shall change suitably.

21.3.4 Self cleaning filters

- i) Body of filter shall conform to carbon steel to IS:210Gr. FG260 or ASTM A 515 Gr. 75/ IS: 2062 and internally painted with epoxy.
- ii) Strainer element shall be constructed of perforated stainless steel plate lined with SS 316 screen (SS 316L for sea water application).
- iii) The mesh size shall be selected on the basis of average clearance between the plates of the plate heat exchanger.

21.3.5 Overhead DM make- up tank

- i) The overhead DM make- up tank shall be of MS construction with plates conforming to IS 2062/ ASTM A 36 and minimum thickness of shell shall be 6 mm. The internal surfaces of the tank shall be epoxy coated or rubber lined in three layers with total thickness not less than 4.5 mm.
- ii) All accessories such as vents, overflow and drain, CO₂ absorber for vent, seal for overflow, manhole & staircase, level indicator, level transmitter and level switch etc. shall be provided.



21.3.6 Alkali preparation/ dosing system

One no. alkali preparation/ dosing tank of minimum 500 litre capacity shall be provided for gravity feed of alkali solution to overhead DM tank and suction piping of ECW system. The tank shall be of MSRL/ stainless steel construction with SS 316 basket, SS 316 agitator with gear reducer unit and other accessories. Alternatively, dosing system may comprise of one no. alkali preparation/ dosing tank alongwith 2x100% dosing pumps in SS 316 construction for dosing of alkali solution at suction of DMCW pumps.

21.3.7 Piping

Piping up to & including 150 NB shall be MS ERW as per IS 1239 (Heavy Grade) and piping above 150 NB shall be fabricated from minimum 6mm thick MS plates as per IS 2062 rolled and welded confirming to IS 3589.

21.4 Sizing Criteria

21.4.1 Pumps

- i) Design flow of pump shall be taken as equipment/process requirement plus 10% margin.
- ii) Design head shall be calculated as per system requirement with 10% margin considered in piping friction head.
- iii) The pump shall be capable of supplying process flow requirement at 47.5 Hz frequency of power supply.
- iv) Continuous rating of the motor at 50⁰C ambient temperature shall have minimum 10% margin over the maximum power requirement of the pump in its entire characteristic curve.

21.4.2 Plate type heat exchangers

- i) Plate heat exchangers shall be designed considering secondary inlet water temperature as 36⁰C¹ and a terminal temperature difference (TTD) of maximum 3⁰C. As such, primary outlet water temperature shall be maximum 39⁰C².
- ii) The temperature rise of secondary cooling water in no case shall exceed the temperature rise of cooling water in the condenser.
- iii) Overall fouling factor shall be considered as minimum 0.8x10⁻⁴ hr m² deg C/kcal.

¹ 33⁰C for sea water based once- through type CW system.

² 36⁰C for sea water based once- through type CW system.



CHAPTER- 22

CONDENSATE POLISHING PLANT

22.1 General

The Condensate polishing Plant shall consist of one set of Condensate polishing Units (CPU) for each TG unit and a common external regeneration system. The CPU for each 660 MW unit shall consist of 3x50% capacity service vessels (4x33.3% for 800 MW unit size).

22.2 Salient Design Data

- i) The design flow (through working vessels) for each condensate polishing unit shall be as per condensate flow corresponding to TG output at VWO with 1% make up and design condenser pressure.
- ii) The following dissolved solids concentration and conditions shall be used as a basis of design for the condensate polishing system (the ionic concentrations indicated below are as such):

Description		Influent	Effluent
a)	Ammonia ppb	100	--
b)	Total dissolved solids (excluding ammonia), ppb	100	20
c)	Silica, ppb	30	5
d)	Iron, ppb	50	5
e)	Sodium, ppb	10	2
f)	Chloride, ppb	10	2
g)	pH	8 – 9.3	--
h)	Effluent conductivity after removal of ammonia and amines (micro mhos/cm) at 25 ^o C.	--	0.1 or less
i)	Suspended solids (crud), ppb	25	5

Under the above operating and design flow through the polisher units, the service run of the vessels shall be minimum 15 days (360 hrs). The mode of CPU operation during this period shall be either in hydrogen cycle or a combination of hydrogen and ammonia cycle maintaining the above effluent quality. Whenever specific conductivity starts increasing from 0.1 micro mhos/cm in the effluent, it shall be deemed that “ammonia break point” has reached and ammonia cycle has commenced.



iii) During start up conditions, quality of the influent shall be considered as below:

- | | | |
|---|---|------|
| a) TDS, ppb | : | 2000 |
| b) Silica, ppb | : | 150 |
| c) Crud, ppb (mostly black oxide of Iron) | : | 1000 |

During start-up condition, the sodium and chloride content at the outlet of CPU shall not exceed 5 ppb and 10 ppb respectively. For design purposes, average crud loading shall be considered as 500 ppb. Under such conditions, total crud content of the effluent shall not exceed 150 ppb.

Useful service run between two regenerations under start-up condition shall not be less than 50 hours.

iv) Under condenser tube-leakage condition, the plant shall be designed for 2000 ppb TDS in addition to the normal influent contaminants stated in as specified at (ii) above. The cation and anion load in 2000 ppb TDS shall be based on the circulating water analysis. Under such condition, both sodium content and silica content of the effluent shall be limited to 20 ppb maximum.

Useful service run between two regeneration under condenser tube leakage condition shall not be less than 50 hours.

- v) The bed cross section shall be such that the average velocity of condensate through it shall not exceed 2 meters/min at the design flow rate. For spherical vessels, average velocity shall be limited to 1.75 meters/min at the design flow. The effective depth of the mixed resin bed in the condensate polisher service vessels shall not be less than 1100mm.
- vi) At the design flow rate, the pressure drop across the polisher service vessels with clean resin bed shall not exceed 2.1 kg/cm². Maximum pressure drop under dirty conditions will be restricted to 3.5 kg/cm² including the pressure drop across effluent resin traps.
- vii) Cation resins shall be regenerated by technical grade hydrochloric acid to IS:265 (concentration 30-33% by volume) and anion resins by sodium hydroxide, rayon grade to IS:252 available as 48% lye or as flakes.

22.3 System Requirements for CPU

i) *Service Vessels*

- a) Design pressure of service vessels shall be equal to shut off pressure of condensate extractions pump + 5% margin. For all other pressure vessels the design pressure shall be at least 8 kg/cm² (g).
- b) Design temperature of the vessel shall take care of all operating regimes including HP-LP bypass operation.



- c) Service vessels shall be designed and constructed in accordance with the ASME code Section- VIII or equivalent international standard or IS 2825. Suitable mill tolerance shall be considered for determining the thickness of the shell and dished ends. A minimum thinning allowance of 2 mm shall be considered for the dished ends.
- d) The service vessels shall be fabricated from carbon steel plates to SA 285C or SA-516 Gr. 70 or equivalent and internally rubber lined to 4.5 mm thickness (minimum). The lining used shall be soft rubber having a shore durometer reading of 40-70 on the A scale, or semi-hard rubber having a durometer reading of 45-70 on the D scale.

ii) *Exchange Resins*

- a) The cation- anion ratio shall be in the range 1.5:1 to 2:1 on volume basis. In case any non ionic resin is used the same shall represent at least 10 % of the bed volume, but not less than 15 cm of the bed depth in the resin separation/ cation regeneration tank.
- b) Base of the ion-exchange resins shall be copolymer of styrene and divinylbenzene forming a macroporous or macroreticular structure. The type of resins shall be as below:
 - 1. Cation resin : Strong acid, with sulfonic acid functional group.
 - 2. Anion resin : Strong base, with quaternary ammonium (type- I) functional group.
 - 3. Inert resin (if applicable) : Non ionic, compatible with the above type resins.
- c) The resin shall be suitable for the condensate temperature that may be achieved in all operating regimes of TG cycle. However, the anion resin shall be suitable for temperature upto 60⁰C.
- d) Resins shall be monosphere with uniformity coefficient of 1.1.

iii) *Emergency Bypass System*

- a) Each CPU shall be provided with an automatic bypass system for the condensate polisher on the condensate inlet and outlet headers of the unit. In the event of excessive pressure differential between the condensate inlet and outlet headers, this control valve will open automatically to bypass requisite quantity of condensate to prevent this pressure differential from exceeding a preset limit.



- b) Either 2x50% capacity control valves or 1x100% control valve shall be provided to achieve proper control under all operating conditions. The control valve(s) shall be able to bypass requisite percentage of rated flow as per any number of the operating service vessels being out of service.
- iv) *Resin Transfer Piping*
 - a) Piping system shall be provided for hydraulic/ hydropneumatic transfer of exhausted/ regenerated resin between service vessels and regeneration area. The resin transfer pipeline shall be of stainless steel type 304 and sized for a flow velocity of between 2 and 3 m/s.
 - b) The length of resin transfer piping shall generally not exceed 300m. The arrangement shall avoid any sharp bends which cause segregation of the mixed resins, and pockets where the resins can get trapped. Suitable observation ports shall be provided in all critical areas to enable for monitoring the resin transfer operations.

22.4 System Requirements for External Regeneration Facility

- i) *Regeneration System*
 - a) The regeneration system shall be external and common to the plant. Under normal conditions, it will hold a complete charge of freshly regenerated and mixed resin, ready for use, in its storage tank. For regeneration, resin from the exhausted exchanger vessel will be transferred hydraulically or hydropneumatically to this facility. The empty exchanger vessel will then be filled up with the already regenerated resin and shall come into service soon after requisite condition is satisfied or as and when desired by the operator. In the meantime, the exhausted resin shall be cleaned, separated, regenerated, mixed and rinsed before being stored for next use. Demineralized water shall be used throughout the regeneration process for backwashing, regenerant diluent, rinsing and resin transfer.
 - b) Two nos. resin separation/ regeneration vessels and one no. mixed resin vessel shall be provided alongwith all internals, fittings and appurtenances for these vessels. An additional vessel containing one spare charge of mixed resin shall also be provided which shall be interconnected to the separation/ mixed vessel.
 - c) Resin injection hopper, complete with a water ejector system shall be provided for resin make-up to the resin separation/ regeneration vessel. The system shall be sized to handle upto 150 liters of as received new resins per single injection.



- d) 2x100% capacity DM water pumps shall be provided for water supply for chemical preparation/dosing and transfer of resin from service vessel to regenerating vessels and vice versa. The pumps shall be horizontal centrifugal type and conform to IS: 1520/IS: 5120 or equivalent without any negative tolerance. All wetted parts of the pump shall be of CF-8M.

ii) *Vessel Free Board*

The pressure vessels in the common external regeneration facility shall be provided with adequate freeboards over the top of the settled resins, to minimize resin loss during regeneration. Minimum freeboards to be provided shall be as below:

- a) Mixed resin Storage vessel : 50%
- b) Resin separation vessel : 75%
- c) Cation regeneration vessel : 75%
- d) Anion regeneration vessel : 75%

iii) *Chemical Dosing System*

- a) 2x100% capacity hydraulically operated ejectors or metering pumps shall be provided each for dosing of acid and alkali. Material of construction shall be suitable for liquid being handled.
- b) Acid ejectors/ metering pumps shall take suction from 2x100% acid measuring tanks and alkali ejectors/ metering pumps from 2x100% alkali day tanks. The capacity of tanks shall be atleast 20% higher than that required from process calculations.
- c) For heating of alkali diluent water, 2x50% electrical heating coil in a MSRL tank shall be provided. The capacity of tank shall be minimum 20% higher than the maximum water demand. The heaters shall be sized for heating the water from 15⁰C to 45⁰C within a time period not more than 5 hours.
- d) Complete system for off-stream ammoniation of the resins, using ammonium hydroxide, shall be provided, if felt necessary, to meet the system requirements.

iv) *Bulk Acid and Alkali Storage Tanks and Unloading Pumps*

- a) The bulk acid & alkali storage tanks shall be horizontal, dished ends, cylindrical type as per BS EN 12285 or equivalent standard. These tanks shall be of mild steel construction with inside surface rubber lined to 4.5 mm thickness in three layers.



b) The requirement of tanks and unloading pumps shall be as below:

1.	Acid storage tanks	2 nos., total storage capacity to hold 30- 33% HCl for 30 days (minimum) requirement of the plant or 30 m ³ whichever is higher.
2.	Alkali storage tanks	2 nos., total storage capacity to hold 48% NaOH for 30 days (minimum) requirement of the plant or 30 m ³ whichever is higher.
3.	Acid unloading pumps	2x100%, 10 m ³ /h each, Hastelloy-B (wetted parts)/ FRP/ PP construction.
4.	Alkali unloading pumps	2x100%, 10 m ³ /h each, SS- 316 construction.

v) *DM Regeneration Water Tank*

One (1) no. DM regeneration water tank of mild steel construction to IS 2062 Gr- B with inside surface rubber lined to 4.5 mm thickness in three layers or epoxy coated shall be provided. The capacity of the tank shall be to hold 1.5 times the DM water required for one regeneration including resin transfer operations subject to minimum capacity of 500 m³. 2x100% capacity pump taking suction from this tank shall be provided for regeneration cum resin transfer operations.

vi) *Effluent Disposal System*

Neutralising pit shall be in two (2) sections of RCC construction with epoxy coating and each section shall have a holding capacity of 1.5 times the waste effluent from each regeneration. Three (3) nos. waste water recirculation/ disposal pumps of horizontal centrifugal type (rubber lined or SS- 316L construction) with priming arrangement shall be provided for waste recirculation and disposal. Each pump shall be designed to pump the waste effluent of one regeneration in less than three (3) hours. Proven agitation system like air agitation, venturi mixing etc. shall be provided in addition to recirculation from pumps.

Provision of dosing acid and alkali shall be provided to neutralise effluents before disposal.

22.5 Control and Operation of Condensate Polishing Plant

22.5.1 The complete control and operation of the CPU and regeneration plant shall be through programmable logic controllers (PLC). The CPU shall be controlled from the CPU control panel, located near the polishing vessels and shall be suitably interlocked with the regeneration system control panel. As an alternative, single PLC can also be provided for control of CPU and regeneration system as per standard proven practice of the OEM.

22.5.2 The CPU control panel shall clearly show the status of each service vessel.



- 22.5.3 It shall be possible to operate the regeneration plant in auto/semi-auto/manual mode. In 'Auto' mode, once the sequence has been initiated, it shall proceed from step to step automatically. In 'Semi-auto' mode each step shall be performed only after initiation by the operator. In 'Manual' mode, complete operation shall be by the operator by operation from the control panel. On PLC failure, it shall be possible to operate the valves by means of manual operation of solenoid valves also.
- 22.5.4 It shall be possible to select each of the CPU vessels for any of the following operations from the CPU control panel:
- i) Service run.
 - ii) Resin transfer from CPU vessel to regeneration plant.
 - iii) Resin transfer from regeneration plant to CPU vessel.
 - iv) Isolation from service.
 - v) Rinse recycle.
- 22.5.5 Manually initiated automatic sequences shall be provided for transferring resin from a vessel to the remote common facility for physical cleaning and chemical regeneration and for returning fresh resin to that vessel. The sequence of resin transfer from CPU vessel to regeneration plant and from regeneration plant to CPU vessel shall be initiated from the condensate polishing unit control panel but shall be controlled by the PLC in the regeneration control panel. Control for chemical dosing system and alkali preparation facility shall also be provided in it.
- 22.5.6 The following operations shall be performed from the regeneration control panel:
- i) Complete regeneration.
 - ii) Resin transfer from CPU vessel to regeneration plant.
 - iii) Resin transfer from regeneration plant to CPU vessel.



CHAPTER- 23

CHEMICAL DOSING SYSTEM

23.1 General

23.1.1 Water chemistry of boiler feed water during normal operation of the plant shall be maintained using combined water treatment (CWT) comprising of oxygen dosing and ammonia dosing in the condensate and feed water as per the guidelines of EPRI, USA/ VGB, Germany/ CEGB, UK/ relevant Japanese standard. The parameters of feed water proposed to be maintained in case of CWT are as below:

- i) Cation conductivity : ≤ 0.15 micro siemens/ cm
- ii) Hydrazine : Nil
- iii) pH value (25⁰C) : 8- 9.3
- iv) Oxygen : 20- 200 ppb
- v) Iron : ≤ 5 ppb
- vi) Silica : ≤ 10 ppb

23.1.2 During startup or chemistry excursions, all volatile type of treatment (AVT) using ammonia and hydrazine dosing shall be used. The following parameters shall be maintained in case of AVT:

- i) Cation conductivity : ≤ 0.25 micro siemens/ cm
- ii) Hydrazine : 10-15 ppb
- iii) pH value (25⁰C) : 9.0- 9.6
- iv) Oxygen : ≤ 7 ppb
- v) Iron : ≤ 10 ppb
- vi) Silica : < 10 ppb

23.1.3 The concentration of sodium and chloride in the condensate at the outlet of CPU shall be considered as 2 ppb each under normal operating conditions. During start-up condition, the sodium and chloride content at the outlet of CPU shall be considered as ≤ 5 and ≤ 10 ppb respectively.

23.2 Oxygen Dosing System

23.2.1 Oxygen shall be dosed in the condensate and in feed water circuit of each unit i.e. at outlet of condensate polishing unit and at the outlet of deaerator (suction line of boiler feed water pumps). Oxygen dosing at additional points shall also be provided, if required, as per manufacturer's standard practice.



- 23.2.2 The dosing system shall be provided with set of oxygen cylinders alongwith required cylinder isolation/ check valves, cylinder manifolds, isolation valves in the common manifold, piping from manifold, dosing (automatic type) valves, check (non-return type) valves, associated control system and instruments etc.
- 23.2.3 The dosing rate of oxygen shall be regulated automatically by control system based on the quality of condensate water and quality of feed water as the case may be.
- 23.2.4 For each dosing location, system shall be designed for dosage rate of 200 ppb. The number of oxygen cylinders to supplied and installed shall cater for one month requirement of each unit.

23.3 All Volatile Treatment (AVT) System

- 23.3.1 Under AVT, ammonia and hydrazine shall be dosed in the feed water at suction lines to the boiler feed pumps as well as at the condensate pumps discharge after the condensate polishing unit. Ammonia shall be used as pH control agent and hydrazine as oxygen scavenger.
- 23.3.2 Each unit shall be provided with skid mounted dosing systems for ammonia and hydrazine, each system comprising of 1x100% capacity measuring tank, 1x100% capacity preparation/ dosing tank and 2x100% metering pumps complete with strainers, piping, valves, fittings, instrumentation and control panel etc. Ammonia and hydrazine shall be received in containers/ barrels and hand pumps (drum pumps) shall be provided for transfer of ammonia and hydrazine to the respective measuring tanks. The flow of chemical from measuring tank to the preparation/ storage tank shall be by gravity.
- 23.3.3 Space provision shall be kept in the main plant building for storage of ammonia and hydrazine containers/ barrels as per one month requirement of each unit. The measuring and preparation/ storage tanks for each chemical shall be sized for one day requirement of the unit. Metering pumps for each chemical shall be of horizontal positive displacement, reciprocating and variable stroke type. All the chemical measuring/ preparation/ storage tanks and metering pumps shall be of SS-316 construction. The provision shall be made for flushing of the metering pumps by the condensate/ DM water.



CHAPTER- 24

EOT CRANE

- 24.1 Two (2) nos. of electrically operated travelling crane with associated auxiliaries alongwith electrical equipment, control & instrumentation as required shall be provided in the turbine hall for erection and maintenance of turbine-generators and their auxiliaries except generator stator. The main hook capacity of each crane shall be 10% over and above the heaviest component/equipment (including lifting beam and slings etc.) to be handled in TG hall and the auxiliary hook capacity shall be minimum 20 Tons.
- 24.2 The EOT crane shall be designed as per Group M5 of IS: 3177 and IS: 807. The bridge girder shall be box section type or braced I - beam type as per standard design of the manufacturer. The lifting hook block assembly shall be ramshorn type for Main Hoist and point hook with shank for Auxiliary Hoist. Ropes shall be steel wire with fibre or steel core construction and drum shall be designed for single layer of ropes only.
- 24.3 The approximate maximum full load speeds shall be as below:
- | | |
|---|-------------------------|
| i) Main hoist | : 1.6 m/ min. |
| ii) Auxiliary hoist | : 7.5 m/ min. |
| iii) Trolley travel | : 15 m/ min. |
| iv) Crane travel | : 30m/ min. |
| v) Creep speed of main & auxiliary hooks and cross & long travels | : 10% of maximum speed. |
- 24.4 For the components designed on the basis of strength, the factor of safety shall not be less than five (5) based on ultimate strength. For compression members, the slenderness ratio shall not exceed 120. In case of other load carrying members and subsidiary members, the slenderness ratio shall not exceed 180. For girders, the maximum span to depth ratio shall be 18 for plate girder and 12 for lattice girder.
- 24.5 Access walkways shall be provided along the bridge girders and for cross over. The width of walkways shall be of minimum 600 mm with hand railing of height 1100 mm.
- 24.6 Electro-hydraulic Thruster Operated Brakes (2x100% capacity) shall be provided for bridge/crab travel and main/auxiliary hoist mechanisms. All brakes shall be adequately sized and braking capacity of all brakes shall be at least 150% of required braking torque.



- 24.7 Three phase squirrel cage Induction motors to be operated from VFD system shall be suitable for speed range and torque without exceeding temperature rise limits. Motors shall conform to latest revision of IS 325, IS 3177.
- 24.8 Materials of construction of various components shall be as below:
- i) Bridge girder, end carriage, lifting beam : Mild steel, Grade E250, Quality B to IS:2062(latest)
 - ii) Lifting hooks : IS:5749 (latest) or IS:15560 (latest) and shall be made of steel (EN-3A)
 - iii) Sheaves, CT/LT wheels : Forged steel
 - iv) Drum : Seamless pipe to ASTM A106 or fabricated rolled section to IS:2062
 - v) Wire rope for main/aux. hoist : IS:2266; 6x36 or 6/37 construction (ungalvanised)
 - vi) Shaft : EN 8 or equivalent
 - vii) Gears/ pinions : EN-9/ EN-24
- 24.9 The design, construction and performance testing of TG hall EOT crane and their associated equipment and accessories shall comply with latest edition of relevant codes/ standards and all currently applicable Statutes, Regulations and the Safety Codes in the locality where the equipment will be installed. All electrical installation work shall comply with the provisions of Indian Electricity Act and Indian Electricity Rules as amended up to date.

Government of India
Central Electricity Authority
Office of the Secretary
2nd Floor, Sewa Bhawan
Ram Krishna Puram New Delhi-110066

No.CEA/TETD-TT/2009/G-23 831-832

Dated : 24th August, 2009**Subject: Committee for Standard Technical Features for Super-critical Units.**

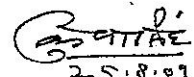
It has been decided to constitute a Committee for preparation of standard technical features for super-critical units of 660/800 MW. The constitution of the Committee shall be as follows:-

- | | | | |
|--------|---|---|---|
| (i) | Member (Thermal), CEA | - | Chairman |
| (ii) | Representative of NTPC | - | Member |
| (iii) | Representative of BHEL | - | Member |
| (iv) | Representative of APGENCO | - | Member |
| (v) | Representative of MAHAGENCO | - | Member |
| (vi) | Representative of RRVUNL | - | Member |
| (vii) | Representative of Tata Power | - | Member |
| (viii) | Representative of Adani Power | - | Member |
| (ix) | Representative of Reliance Power | - | Member |
| (x) | Representative of L&T-MHI | - | Member |
| (xi) | Representative of Toshiba India | - | Member |
| (xii) | Representative of Alstom India | - | Member |
| (xiii) | Representative of Tata Consulting
Engrs. | - | Member |
| (xiv) | Representative of DCPL | - | Member |
| (xv) | Chief Engineer (TE&TD), CEA | - | Member Secretary
(Telefax : 011-26103488)
E-mail : schander1950@yahoo.co.in |

The terms of reference of the Committee shall be as follows:-

Preparation of standard technical features for Steam generator & auxiliaries and Steam turbine generator & auxiliaries for 660/800 MW supercritical units.

The Committee shall submit its report within 3 months.


 25.8.09
 (K.P. Singh)
 Secretary

To :

1. Chairman & Managing Director, National Thermal Power Corporation Ltd., NTPC Bhawan, Core-7, Scope Complex, 7, Institutional Area, Lodi Road, New Delhi - 110 003
Fax No. 011-24363050
2. Chairman & Managing Director, Bharat Heavy Electricals Ltd., BHEL House, Asiad Village, Siri Fort, New Delhi - 49
Fax No. 011-26493659
3. Managing Director, APGENCO, Vidyut Soudha, Khairatabad, Hyderabad-500 082
Fax No. 040-23317663
4. Managing Director, MAHAGENCO, Prakashgad, Plot No. - G-9, Bandra (East), Mumbai - 400051
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5. Chairman & Managing Director, RRVUNL, Vidyut Bhawan, Jan Path, Jyoti Nagar, Jaipur - 302 005
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6. Managing Director, Tata Power Co. Ltd., Bombay House, 24-Homi Modi Road, Nariman Point, Mumbai-400001
Fax No. 022-66658877
7. Shri Raj Kumar Gupta, Director, Adani Power Ltd., 7th Floor, Sambav House, Bodakdev, Judges Bunglow Road, Ahmedabad - 380015
Fax No. 079-2555 7177
8. Shri J.P. Chalasani, Chief Executive, Reliance Power Ltd., H-Block, Dhirubhai Ambani Knowledge City, CoperKharaine, Navi Mumbai - 400710
Fax No. 022-30386999/30376633
9. Shri Ravi Uppal, CEO & Managing Director, L&T Power Ltd., L&T Engg. Centre, Near Chhani Jakat Naka, Vadodara-390002 (Gujarat)
Fax No. 0265-2452930
10. Mr. Itaru Ishibashi, Managing Director, Toshiba-JSW Turbine & Generator Pvt. Ltd., TVH BELICIA, TOWERS, Phase-II, 8th Floor, 1st Main Road, MRC Nagar, R.A. Puram, Chennai-600028
Fax No. 044-66330001

With the request to nominate one member for the Committee and furnish his contact details / e-mail address to the Member Secretary.

11. Mr. Emmanuel Colombier, Vice Chairman & Managing Director, Alstom India, IHDP Building, Plot # 7, Sector 127, NOIDA – 201301 (U.P.)
Fax No. 0120- 4731200
12. Shri R. Srinivasan, Managing Director, Tata Consulting Engineers, Sheriff Centre, 73/1, St. Marks Road, Bangalore – 560001
Fax No. : 080- 22274873
13. Shri G.C. Nundy, Vice Chairman & Managing Director, Development Consultants Pvt. Ltd., 24, Park Street, Kolkata-700 016
Fax No.: 033- 22492897

With the request to nominate one member for the Committee and furnish his contact details / e-mail address to the Member Secretary.

Copy to : 1. Member (Thermal), CEA
2. Chief Engineer (TE&TD), CEA

Copy for kind information to :

Chairperson, CEA