

Purchase Qualification Requirement (PQR)

The vendor is required to meet the provenness criteria of critical equipment, auxiliaries, systems and bought out items for a 660MW rating TG sets as per criteria stipulated below:

Provenness Criteria for equipment(s):

1. Vendor should have previously designed (either by itself or under collaboration / licensing agreement), manufactured / got manufactured, supplied, erected/ supervised erection and commissioned/ supervised commissioning of the type and minimum equipment rating of Air Cooled Condenser as stipulated below such that the ACC are in successful operation in at least one (1) plant for a period not less than one (1) year as on date of submission of PQR bid.

| Slno | Name of Equipment | Type of Equipment | Equipment Rating |
|------|--|--|---|
| 1 | Air Cooled Condenser(ACC) | Direct Air Cooled Forced Cooling | ACC of a 500MW or higher size rating |
| | 1 (a) Condenser Air Evacuation system | Liquid Ring type for steam generator sets | Free dry Air Capacity 30 SCFM at 1" Hg(abs) at 21.1 deg C |
| | 1 (b) Condensate Extraction Pumps(CEP) | Vertical, canister with double suction first stage impeller for steam generator sets | Capacity not less than 900 Ton/ hr and total developed Head not less than 30 Kg/cm2 However, offer with Horizontal Pump may be considered subject to approval/ acceptance on later date. |

Vendor shall offer and supply only the type of the above equipment(s) for which it, itself or the manufacturer proposed by the vendor for the above equipment(s) at 1(a) and 1(b) is qualified.

In case, vendor is not manufacturer of equipment(s) at 1(a) and 1(b), then vendor shall source the equipment(s) from such manufacturer(s) who meets the qualification/ provenness criteria of the respective equipment(s) specified above. The proposed sub-vendor(s) for 1(a) and 1(b) should have designed (either by itself or under collaboration / licensing agreement), manufactured / got manufactured the respective equipment(s) of the type and minimum equipment rating as stipulated above such that the respective equipment(s) are in successful operation in at least one (1) plant for a period not less than one (1) year as on date of submission of PQR bid.

2. In case vendor is not manufacturer of proven equipment(s) as per clause 1, but is a manufacturer for such equipment(s) for at least 1 no. 200 MW rating (for equipment at slno.1 of clause 1) which has been successfully running since last 1 year, and the vendor can manufacture such equipment(s) for 660MW supercritical units also, provided it has collaboration or valid licensing agreement for Design, Engineering, Manufacturing, and Supply of such equipment in India from a

manufacturer who meet the requirements stipulated at clause 1 above for the respective equipment.

3. A JV / Subsidiary Company formed for manufacturing and supply of equipment in India can also manufacture such equipment, provided that it has a valid collaboration or licensing agreement for design, engineering, manufacturing of such equipment(s) in India with a qualified equipment manufacturer who meets the requirements stipulated at clause 1 above (or the technology provider of the qualified equipment manufacturer). Further, in such a case, such qualified equipment manufacturers should have, directly or indirectly through its holding company/ subsidiary company, at least 26% equity participation in the Indian Joint Venture Company/ Subsidiary Company, which shall be maintained for a lock-in period of seven (7) years from the date of incorporation of such Joint Venture/ Subsidiary or upto the end of defect liability period of the contract, whichever is later. In addition, the sub-vendor along with the Indian Joint Venture Company/ Subsidiary Company, qualified equipment manufacturers and its holding/ subsidiary Company, as applicable, shall furnish DJU(Deed of Joint Undertaking) in which executants of the DJU shall be jointly and severally liable for the successful performance of the equipment. Format of the DJU to be provided later. The DJU shall be submitted prior to the placement of order on the approved sub-vendor for particular equipment. In case of award, each executants of the DJU be required to furnish an on demand bank guarantee for INR 1.5 Million (Rupees One and Half Million) for each equipment.
4. Before taking up the manufacturing of such equipment(s) as per point 2 and 3 above, the vendor / its sub vendor(s) must create (or should have created) manufacturing and testing facilities at its works as per Collaborator / licensor's design, manufacturing and quality control system for such equipment duly certified by the Collaborator / licensor.
Further, the Collaborator / Licensor shall provide (or should have provided) all design, design calculation, manufacturing drawings and must provide (or should have provided) technical and quality surveillance assistance and supervision during manufacturing, erection, testing, commissioning of equipment.

The BHEL reserve the right to fully satisfy himself regarding capability and capacity of vendor / its sub-vendors and proposed arrangement and may prescribe additional requirement before allowing manufacture of the equipment.

The vendors should confirm their acceptance for submission of all documents / information required for registration with BHEL and approval of NTPC.

Bidder has to provide documents/ details required for proven criteria mentioned in clause 1, 2, 3 and 4 above of PQR as per Annexure-1.

Data required from Vendor:

1. Supporting documents / Details as per annexure-1 for proven criteria as mentioned in clause no 1, 2, 3 and 4 stipulated above.
2. The scope of supplies and services shall be tentatively as per annexure-2.
3. The board technical requirement (not limited to) shall be as per annexure-3.
4. Following preliminary data regarding General Arrangement / Design of Air Cooled Condenser for 660MW rating based on tentative Design Data as per annexure-4 to be provided:
 - Minimum elevation of steam duct at LP Exhaust connection.
 - Cross-sectional view, sizing (including height), routing & layout of Steam exhaust duct from LP turbine to ACC
 - Size, Elevation and layout of vacuum pump, condensate extraction pump, condensate storage tank, drain pot, drain pump, elevators, stairs, walkways, number of modules, piping ,LP exhaust line , rupture disc, control room etc.
 - Location of ACC columns, its tentative size is required & clear distance between ACC columns.
 - Minimum Distance between TG building column and first column of ACC.
 - Cross-sectional view showing clear height available below ACC
 - Suggestive location for nozzles (like TDBFP exhaust, LP bypass dump line, LPHs vent, F/T vents/drains, GSC recirculation etc.) which shall be mounted upon steam exhaust duct from LPT, accordingly provision shall be kept.
 - Vendor to furnish the data sheet of equipment(s) as per attached annexure-5.
 - Vendor to furnish the auxiliary power consumption as per attached annexure-6.
5. Details such as technical features, experience details, product catalogue, reference list or any other relevant information.
6. Documents required for all Categories as per clause no. 1, 2, 3 and 4 of PQR are as below:
 - a. Reference list.
 - b. List of equipments manufactured in-house.
 - c. List of Bought Out items along with vendors list of each equipments with experience details with respect to size rating and years of operation.
 - d. List of equipments sourced from outside along with vendors list of each equipments with experience details with respect to size rating and years of operation.
 - e. Experience details satisfying the tentative scope of supplies and deliveries clearly mentioning the exclusions if any as per Annexure-2.

ANNEXURE-1

Documents/Details required for proven criteria mentioned in clause 1, 2, 3 and 4 of PQR

For Clause 1 of PQR:

1. In case of OEM:

- i. Copy of purchase Order (un-priced) for items stipulated in the clause 1 of PQR as per equipment rating specified at a plant. - Required at EOI stage.
- ii. Certificate of successful operation for at least 1 year of the equipment supplied at the plant mentioned in point (i) above duly certified from end user to be provided or confirmation that it will be provided at the time of enquiry.

2. In case of Vender under Collaboration/ Licensing Agreement:

- i. Copy of purchase Order (un-priced) for items stipulated in the clause 1 of PQR as per equipment rating specified at a plant. - Required at EOI stage.
- ii. Certificate of successful operation for at least 1 year of the equipment supplied at the plant mentioned in point (i) above duly certified from end user to be provided or confirmation that it will be provided at the time of enquiry.
- iii. MOU/ certificate of collaboration/ licensing agreement satisfying clause 1 of PQR to be provided or confirmation that it will be provided at the time of enquiry.

For Clause 2 & 3 of PQR:

- i. Copy of purchase Order (un-priced) for items stipulated in the clause 1 of PQR as per equipment rating specified at a plant. -Required at EOI stage
- ii. Certificate of successful operation for at least 1 year of the equipment supplied at the plant mentioned in point (i) above duly certified from end user to be provided or confirmation that it will be provided at the time of enquiry.
- iii. MOU/ certificate of collaboration/ licensing agreement satisfying clause 2 and 4 of PQR to be provided or confirmation that it will be provided at the time of enquiry.
- iv. Details of establishment for manufacturing and testing facilities at its works as per Collaborator / licensor's design, manufacturing and quality control system for such equipment duly certified by the Collaborator / licensor to be provided or confirmation that it will be provided at the time of enquiry.

Scope of Supply & Services

The scope of work for the equipment, material and system to be furnished in accordance specification shall include design, engineering, manufacture, fabrication, assembly, pre-shipment testing at manufacturer's works, proper packing for transportation, delivery at plant site, unloading, storage, installation, interconnection with related plant and equipment, calibration, performance testing, commissioning and putting the ACC together with all accessories, auxiliaries and associated equipment.

| SL. | SYSTEM/EQUIPMENT | REMARKS |
|------------|--|---|
| 1 | From the bottom exhaust of LP Turbine to the discharge of CEP Including CEP recirculation valve such as vacuum breaker valve, transition piece, main steam duct with bellow, distribution manifold, rupture disc, risers, fin tube bundles, fans, motors, all supporting structure, condensate tank, drain pot, interfaces for all connections etc.. | Terminal pt shall be 2M from A-Row of TG column towards ACC except Steam exhaust connection. |
| 2 | Bottom steam exhaust of LP turbine shall be welded connection with ACC. | |
| 3 | Control System(DCS/PLC) and Control Panel (of ACC) | In case DCS by BHEL, bidder to provide necessary inputs like Drive list, I/O list, Control logics, Cable schedule & interconnection. |
| 4 | Drain pot (Hot-Well), Condensate tank. | |
| 5 | Piping, Instruments, valves within battery limits of ACC. | Battery limits shall be 2M from A-Row of TG column towards ACC. |
| 6 | Connecting pipeline from Condensate storage tank to Condensate tank. | |
| 7 | Control system of DM water make-up Valve & Valve and control system of Condensate level in Condensate tank Including piping. | Control System shall be realized in DCS. |
| 8 | One no elevator. | |
| 9 | 2X 100% Drain pump for each unit along with all accessories, drives, associated piping and valves, Instrumentation and control etc. | |
| 10 | 3X50% capacity motor driven condensate extraction pumps for each unit along with all accessories, drives, suction strainers, associated piping and valves, instrumentation and control etc. | Control System shall be realized in DCS. Bidder to provide necessary inputs like Drive list, I/O list, Control logics, Cable schedule & interconnection |
| 11 | Recirculation valve and piping of CEP | |
| 12 | Air Cooled Condenser Air Evacuation system complete with 2X100% vacuum pumps, associated motors, all accessories, associated piping, valves and fittings, specialties, duplex filters, instrumentation and control etc along with 1X100% hogging pump | PLC based control system |

| | | |
|----|---|--|
| 13 | Steam exhaust duct from LPT exhaust to ACC tube bundle(outside TG Hall). Including expansion bellows, spring hangers, rupture discs and supporting structures. | |
| 14 | Semi-automatic Fin cleaning system Independent for each side along the length of ACC Complete with Water storage tank, Fin cleaning pumps, piping, valves, Instruments, fittings, cleaning nozzle sets, motorized ladders, flexible hoses etc. | |
| 15 | Monorail and hoist arrangement for handling fan and motor, vacuum pump etc | |
| 16 | Cable rack Including walkways between STG building and ACC with supporting structures. | |
| 17 | Design and supply of erection drawings for Civil structure, foundation and loading drawings. NOTE:-Geo-Technical data as received from NTPC is attached herewith. BHEL shall carry detailed geo-Technical investigation during contract stage & same shall be provided to the bidder. However, no extra amount shall be payable to bidder on account of variance in soil data. | A.) ACC on Steel super Structure: All Steel Structure to be supplied & erected by bidder. Civil foundation shall be designed by bidder and constructed by BHEL. BOQ of civil foundations shall be furnished by bidder at proposal stage. B.) ACC on RCC columns: All Steel structure to be supplied & erected by bidder. RCC columns & Civil foundation shall be designed by bidder and constructed by BHEL. BOQ of civil foundation & column shall be furnished by bidder at proposal stage. |
| 18 | Erection, commissioning and performance testing. | Other than concrete work. |
| 19 | Air Conditioned room for ACC control system/panels and MCC room for ACC outside TG hall. (Size of Room and load of AC) | Erection and material supply for Control Room and MCC room shall be done by BHEL based on required design inputs by vendor |
| 20 | Instrument air supply for vacuum pump system valves (Quantity: Negligible, Pressure :at 5-10 kg/cm2) | Terminal pt shall be 2M from A-Row from TG column towards ACC |
| 21 | ACW supply for vacuum pump heat exchanger (Vacuum pump is located in ACC area) | Terminal pt shall be 2M from A-Row from TG column towards ACC |
| 22 | Supply of transformer for ACC MCC | BHEL scope |
| 23 | Supply of bus duct from transformer to ACC MCC | BHEL scope |
| 24 | Supply of power cables upto transformer | BHEL scope |
| 25 | Supply of ACC MCC | |
| 26 | Supply of power and control cables from ACC MCC and Control Panel to ACC loads/ field instruments. | |
| 27 | UPS for ACC control system. | |
| 28 | Supply of cable trays and cable tray accessories upto Air Cooled condenser MCC and to ACC loads and field equipment. | |

| | | |
|-----------|---|---|
| 29 | Support for exhaust Pipe from Turbine | Execution by BHEL based on required inputs from Vendor. |
| 30 | Lighting for ACC area. | Supply by BHEL, design by vendor |
| 31 | Above ground earthing for ACC area. | Supply by BHEL, design by vendor |
| 32 | Lightening protection for ACC area. | Supply by BHEL, design by vendor |
| 33 | 3-D modeling of ACC alongwith all components for Layout | |

The scope of supply is not limited as specified. Activities required for completeness of the package shall be in scope of supply.

If there is any deviation regarding scope of supply. Vendor to indicate the same. BHEL reserves the right to accept or reject the same.

Technical Requirements

Air Cooled Condenser

TYPE:

Direct air cooled, forced cooling type.

Air cooled condenser and associated system shall be designed as per HEI for Air cooled condensers. The exhaust steam from the turbine shall be cooled using an Air Cooled Condenser with forced convection air as a cooling medium. Expanded steam from the Steam Turbine is condensing through the condenser tubes. Cooling air is drawn over the condenser tubes by motor fans to produce condensate. The condensate is collected in a common condensate tank and returned to the feed water tank / deaerator via the condensate pumps. The Air cooled condenser shall be direct air cooled condenser with finned tubes and A- frames with all associated auxiliaries, integral piping and elevator.

DESIGN AND CONSTRUCTION REQUIREMENTS

ACC Performance

- ASME PTC 30.1/VGB 131 Me should be followed for reporting thermal performance characteristics of mechanical draft air-cooled steam condensers (ACC) operating under vacuum conditions.
- Under all the operating conditions, while passing the required steam flows as per the relevant heat balances, the condenser should be able to accept the entire steam without increasing the exhaust hood temperature and condenser pressure beyond the maximum permissible value.
- The ACC shall be capable of condensing the steam flows under the following, but not limited to conditions:
 - The whole of the steam from the steam turbine under Turbine VWO + 3% makeup and all normal operating conditions, and at specified design ambient air temperature.
 - Attenuated steam flow from the steam by pass systems under transient operation (start-up, shut down, unit trip) (Bypass capacity is 60% more of main steam flow at VWO 3% MU).
 - Maximum oxygen content of condensate leaving the condensate collection tank shall be 0.015 cc/litre over 50-100% load range.
 - Condensate temperature at all loads shall not be less than the saturation temperature corresponding to condenser pressure.
 - The condenser vacuum shall be measured with a vacuum grid utilizing ASME basket tips. The grid is fitted at 300 mm downstream of LP turbine exhaust connection.

- Vibration of the cooling system structure shall not exceed the recommendations given in standards as applicable. Mechanical vibration measured at gear box and motor bearing housing, shall be assessed in accordance with relevant standards and shall not exceed the limits of the “acceptable” assessment level of generally accepted technical standards under normal operating conditions.
- Each fan shall be free from harmful surge or pulse effects arising from gusts of wind or from parallel operation with other fans.
- The acceptable sound pressure level, while all the fans are working shall not exceed 85 dBA measured at a height of 1.5 m above floor level in elevation and at a distance of one 1.0 metre horizontally from the nearest surface of any equipment / machine.
- The procedure for determining noise level shall be in accordance with ISO 12065 standard.

ACC Design

- The Air Cooled Condenser (ACC) shall be of Direct air cooled forced cooling type. The Air cooled condenser (ACC) shall be built to a standard and proven design and complying with the requirements of the Heat Exchange Institute (HEI), ISO-13706 and ASME VIII as applicable
- For the purposes of sizing and establishing the rated capacity of the condensate collection tank, condensate transfer pumps (including suction strainers) the condensate system shall be sized as per HEI for five (5) minutes’ storage capacity (between normal and low-low level) of total design flow with the turbine operating at VWO+ 3% make-up, and design condenser pressure, but not limited to the following conditions.
 - The low-low level of condensate tank shall be at least 200 mm above the bottom of the tank.
 - Operation of the steam from the Steam Turbine under Turbine VWO + 3% Make-up and all normal operating conditions plus; all drains plus; a suitable margin as per ACC Supplier’s design philosophy.
 - Or the highest condensate flow resulting from the parallel operation of the turbine by pass system and the steam turbine.
- All drains shall include the drains from the flash tanks, drains from LP Heaters and gland steam condenser plus pump gland seal return water and the maximum specified make-up water flow.
- Design of air removal section to cool the air and vapor mixture to at least 4.17 deg.C below saturation temperature corresponding to guaranteed condenser pressure. Connections to air evacuation pumps shall be made at this section.
- The condensate collection tank shall be designed and arranged to ensure that there should be

zero air leakage directly into the condensate below the condensate level in the tank.

- Stand pipes with necessary connections for instruments, with water level gauges and isolation valves.
- ACC shall include:-
 - i. Condenser modules, finned heat exchanger tube bundles, steam and condensate collection header.
 - ii. Complete air moving system incl. fans, speed reducer, couplings, electric motors, fan support bridges and equipment required for safe operation.
 - iii. Steam distributing system from steam turbine outlet to the ACC unit including main steam duct, steam distribution manifold, steam header.
 - iv. Condensate tank including connections for makeup water with condensate strainer, standpipe, manholes, nozzles connection, hand railing etc.
 - v. A Condensate drain pot shall be provided for receiving drains water from the ACC steam duct, Steam Turbine internal drains including L P Heaters' drains, flash tanks and gland steam drains and be complete with suction strainers, suction isolation, discharge control & isolation valves, Minimum recirculation valve.
 - vi. Steam duct shall be welded to turbine exhaust.
 - vii. Connections for Steam turbine HP-LP bypass connections.
 - viii. Selection of fans and speed reducer shall be as per HEI.
 - ix. Fin tube cleaning system of semi automatic type as per HEI is to be provided. The fin tube bundles shall be cleaned using high pressure water. Cooling fins shall be designed to withstand the cooling water jet pressure.
 - x. Necessary vacuum breaker valves and provision of rupture devices as per HEI.
 - xi. Provisions for accommodating expansion and contraction with changes in thermal load.
 - xii. Steam duct connecting turbine exhaust flange to steam distribution manifold shall include expansion joints, rupture discs, inspection ports, drain pots and necessary vent and drain connections.
 - xiii. All necessary structures for bundles, fans, motor, gearboxes, piping, cable rack, lighting, etc., with inspection platforms, stairways, ladders for access to all instruments, drives, valves, and to operation, maintenance and inspection locations e.g. duct manholes). At least one staircase and one caged ladder to be provided to get access to the ACC main platform.

- xiv. All structures for supporting ACC as defined elsewhere in the specification.
 - xv. Painting of all exposed parts of ACC and structure shall be as specified elsewhere in the specification.
 - xvi. The thermal, hydraulic and mechanical design calculation for checking the equipment capability.
 - xvii. Provision of air evacuation pumps. Condenser to be designed for minimum air leakage and under normal operating conditions, the air leakage in the condenser not to exceed more than 50% of design value taken for sizing of vacuum pumps. The same shall be demonstrated at site under actual operating condition failing which bidder shall carryout necessary modifications.
 - xviii. Provision for leakage testing of ACC and associated system along with blanking arrangement.
 - xix. The design of the ACC shall be based on proven design practices and the supplier shall indicate the provision made for wind effects on the performance of ACC.
 - xx. ACC shall be design taking into account the environmental conditions and the seismic condition.
 - xxi. Corrosion allowance shall be as per HEI.
 - xxii. The inlets to each fan shall be protected with a screen capable of preventing objects/foreign material.
 - xxiii. Leakage testing shall be done as per HEI.
 - xxiv. Fouling factors on steam side and air side shall be considered as per HEI.
- Complete fan assemblies comprised of blades, hub and seal disks to provide optimum efficiencies over the expected range of ambient temperature. Suitable arrangement shall be provided to improve the entering airflow characteristics upstream of the fan. Fans shall be designed as per HEI.
 - Fan blade (material) shall be as per standard practice.
 - Fan blade systems shall be designed such that there are no natural frequencies set up between the intended operations of the fans and the ACC structure.
 - Steam dumping device to accept the steam from HP-LP bypass with necessary spray water including abnormal conditions like HP heaters out of service etc.
 - Design for 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 and other miscellaneous drains.

- The gearbox shall be designed as per **AGMA** and design life of the gearbox shall be 100 000 hours. Gear box shall be designed for continuous operation. All the bearings in the gearbox shall be designed for a life of 100,000 hours. Gear box shall have self contained lubrication arrangement of sump oil / oil pump type as per standard practice of the bidder. All couplings shall be as per standard practice.

ACC Structures

- (a) The ACC shall be supported by a structural steel framework / RCC columns at a height sufficient to allow proper air distribution to each fan.
- (b) Each individual delta form section or cell shall be complete with a fan assembly, remote temperature instrumentation for both steam and condensate, walkway, dividing wall and access doors.
- (c) The ACC sections shall be constructed to ensure they remain tight under all pressures and stresses to which they may be subjected during operation, transport and handling. Special precautions shall be taken to ensure that the completed sections are free from distortion due to welding or any other cause.
- (d) All structural bolts shall be suitable for the corrosive atmosphere and shall be provided with suitable lock nut stop to prevent loosening due to vibration. Where necessary the structures shall be welded for maximum durability and particular attention paid to achieving the specified performance of the anti-corrosion finishes on all surfaces.
- (e) The design shall include features to minimize wind interference on the ACC or fan operation.
- (f) Permanent lifting beams shall be installed inside each delta form section to enable the drive motor to be removed from the gearbox or fan assembly without disturbing the gearbox or fan assembly.
- (g) The inlets to each fan shall be protected with a screen capable of preventing objects/foreign materials
- (h) A suitable handling facility shall be provided to lift and lower the fully bladed fan assembly and gear box after removal of the drive motor. The Bidder shall provide a method statement on how a complete fan assembly is raised and lowered during maintenance activities.
- (i) Suitable electric hoist shall be provided raising and lowering materials from ground level to the fan level.

- (j) The ACC structures shall be complete with all the necessary walkways, access stairs and handrails to ensure safe access and working conditions at this elevated height.
- (k) One number passenger cum good elevator for ACC (for each unit) to access ACC fan deck level from ground level.

Condenser Air Evacuation System

- i) Each unit shall consist of 2x100% vacuum pumps for holding operation with all accessories and instrumentation for condenser air evacuation with PLC based control system shall be provided consisting of Control desk, PLC panels, I/O racks, along with its power supply arrangement etc. for the control of each pump.
 - (a) Pumps shall be sized as per latest HEI requirements. Capacity of each pump 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 4.17 degC below temperature corresponding to absolute suction pressure shall not be less than 30 scfm (51 M3 per hour under standard condition i.e 760 mm of Hg (abs) and 21.1 deg. C) .
 - (b) The capacity of each pump during hogging shall not be less than 800 scfm (1360 m3/per hour) under standard conditions i.e. 760 mm of Hg. (abs) and 21.1 deg. C) at 10inch (254 mm) of Hg (abs).
- ii) One (01) start up hogging vacuum pump per unit with capacity not be less than 800scfm (1360 m3 per hour) under standard conditions i.e. 760 mm of Hg. (abs) and 21.1 deg. C) at 10 inch (254 mm) of Hg (abs) shall be provided. All three pumps running together should be able to bring condenser pressure from atmospheric pressure to 10 inch of Hg (abs) in 30 minutes.

PLC based control system shall be provided for Vacuum pumps as follows-

Independent PLC based control system consisting of Control desk, PLC panels, I/O racks, along with its power supply arrangement etc. for the control of each Vacuum pump.

Condensate Extraction pump

3 x 50% capacity motor driven condensate extraction pumps for each unit along with all accessories, drives, suction strainers, associated piping, and valves, flow elements with flow transmitter and indicators, instrumentation and control etc. including one number canister drainage pump per station shall be provided

- i) Pump sizing
 - a) Design Capacity:
Combined flow of 2x50% condensate extraction pumps to be based on 15%

margin over highest Condensate flow envisaged during unit operation (excluding HP/LP by pass operation).

Design Head:

Corresponding to above considering 10% margin over deaerator pressure.

- b) Best efficiency point; Combined flow of 2x50% CEPs shall be based on TG unit EMCR and corresponding head. Best efficiency point of the selected pump shall be preferably corresponding to above point.
- c) Maximum Capability; One pump capable of handling the flow and head corresponding to 65% unit load.
- d) Other Capability;
 - 2 pumps shall be capable of handling the flow corresponding to Unit EMCR, all HPH out, 3% m.u and worst condenser pressure at 47.5 Hz.
 - 2 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.
- ii) Motor Rating; Motor rating at 50 deg.C ambient temperature not less than the maximum load demand of its driven equipment in its entire operation at frequency variations from 47.5Hz to 51.5Hz and motor not to be overloaded during any mode of operations of driven equipment.

Control system is to be realised in plant DCS, bidder to provide necessary inputs like Drive list, I/O list, Control logics, Cable schedule & interconnection.

LV SWITCHGEARS AND LV CABLES

The scope of work includes the following for feeding all the LV Loads of the ACC.
The major LT Switchgear shall include the following:

415 Volt Switchgears

415 Volt Motor Control Centers

415 Volt AC Distribution Boards

220 V DC/110 V DC/48 V DC Distribution Boards

415 Volt AC Fuse Boards

220 Volt DC/110 V DC Fuse Boards

Local Motor Starters, Local Push Button Stations, Telescopic Trolley/ Welding / Lighting

LV Cables

Preparation of control cable interconnection schedules, supply and termination of control cables for the following.

- a. LV Switchgear / MCC panel (motor outgoing) and Motor auxiliary / space heater terminal box / Emergency Stop Push Button
- b. Any other interlock envisaged during detailed engineering

All switchgear, Motor Control Centers (MCCs) & AC/DC distribution boards, etc. shall have at least 20% or minimum two (whichever is higher) fully equipped switch-fuse modules of each rating as spares, uniformly distributed over different vertical sections. In addition, all switchgears, MCCs, AC/DC boards, etc., shall have as spares at least twenty (20%) percent of starter modules/MCCB module or at least one module (whichever is higher) of each physical size, equipped for the rating of the largest auxiliary fed from that size of module. Contractor shall provide power supply distribution panels/cabinets/boxes for sub-distribution of DC/Main UPS//utility feeders on as required basis. The power supply distribution box shall included change over circuitry, switch fuse units, MCB's, terminal blocks etc suitable for application.

MOTORS

Motors along with couplings and coupling guards for all rotating auxiliaries covered under this package.

For the purpose of design of equipment/systems, an ambient temperature of 50 deg. Centigrade and relative humidity of 95% (at 40 deg C) shall be considered. The equipment shall operate in a highly polluted environment. All equipment shall be suitable for rated frequency of 50 Hz with a variation of +3% & -5%, and 10% combined variation of voltage and frequency unless specifically brought out in the specification, fully compatible electrical system, equipment, accessories and services. Paint shade shall be as per RAL 5012 (Blue) for indoor and outdoor equipment.

Degree of Protection

Degree of protection for various enclosures as per IS:4691, IEC60034-05 shall be as follows :-

| | | |
|----------------------------|---|-------|
| i) Indoor motors | - | IP 54 |
| ii) Outdoor motors | - | IP 55 |
| iii) Cable box-indoor area | - | IP 54 |
| iv) Cable box-Outdoor area | - | IP 55 |

CODES AND STANDARDS

| | | |
|---------------------------------|---|------------------------|
| 1) Three phase induction motors | : | IS:325, IEC:60034 |
| 2) Single phase AC motors | : | IS:996, IEC:60034 |
| 3) Crane duty motors | : | IS:3177, IEC:60034 |
| 4) DC motors/generators | : | IS:4722 |
| 5) Energy Efficient motors | : | IS 12615, IEC:60034-30 |

Earthing and Lightning Protection

Aboveground earthing mat /Grounding and lightning protection for the complete ACC, switchyard and equipment.

Station Lighting

Station lighting system for the ACC, buildings and equipment. Lighting fixtures complete with lamps & accessories, Lighting Panels, Receptacles, Switch boxes. Conduits. Lighting Wires, Ceiling fans with regulators, Lighting poles. Lighting masts, Earth wires and rods, Junction boxes, Battery operated automatic self contained lighting fixture, Maintenance ladders as required are to be included.

CONTROL AND INSTRUMENTATION

A stand- alone common system / provision of control system to be realised in plant DCS shall be provided for control and monitoring of ACC units with separate control room and control panels (in case of stand lone system). Control & Instrumentation system for control, monitoring and operation of entire ACC including all the systems, equipments etc covered under specification(like Fans ,Motors etc , Electrical sections for /MCC/SWGR/ Transformer etc.), in all regimes of operation in safe and most efficient manner.

In case of control system is realised in plant DCS, bidder to provide necessary inputs like Drive list, I/O list, Control logics, Cable schedule & interconnection.

The scope of work for the equipment, material and system to be furnished in accordance with this specification shall include design, engineering, manufacture, fabrication, assembly, pre-shipment testing at manufacturer's works, proper packing for transportation, delivery at plant site, unloading, storage, installation, interconnection with related plant and equipment, calibration, testing, commissioning and putting the Control and Instrumentation System together with all accessories, auxiliaries and associated equipment control system shall comply to the requirement of combustion control implosion protection as stipulated in NFPA-85. Automatic unit start-up and shutdown controls under various regimes of operation shall also be implemented.

INSTRUMENTATION

All the primary Instruments like thermocouples & RTDs, transducers, Ultrasonic / Guided Radar type level transmitters, Pressure/Diff. Pressure/Temperature/Flow/Level transmitters & Gauges, Vibration sensor, etc. shall be provided on as required basis meeting functional redundancy, available and reliability requirements of the specification sufficient quantities to enable the functioning in all regimes of operation.

INSTRUMENTATIONCABLES, CONTROL & POWER SUPPLY CABLES & CABLES SUB-TRAYS

All instrumentation cables twisted & shielded, PVC insulated & sheathed with FRLS properties, including thermocouple extension cables (PVC / extruded FEP insulated &

sheathed) and prefabricated cables (with plug-in connectors), Power Supply distribution cables, optical fibre cables as applicable for interconnection of all equipment/system/devices Fans/Motors/PLC/MCC/LT SWGR//Etc. shall be supplied, terminated and laid on as required basis.

DESIGN DATA

The tentative design data for typical 660MW rating Air Cooled Condenser and its associated components are as below:-

| | Case-1 | Case-2 | Case-3 | Case4 | Case-5 |
|---|------------------------|----------------------------|----------------------|----------------------|----------------------|
| 1. Steam Flow from LP Exhaust (T/Hr) | : 1151 | 1160 | 1173 | 1194 | 1220 |
| 2. Condenser Back Pressure (ata) | : 0.145 | 0.168 | 0.185 | 0.223 | 0.2665 |
| 3. Ambient Air Temperature(Deg C) | : 38 | 38 | 38 | 38 | 38 |
| 4. Worst Ambient Air Temperature(Deg C) | : 42 | 42 | 42 | 42 | 42 |
| 5. Steam Dryness Fraction | : 0.93 | 0.933 | 0.935 | 0.94 | 0.945 |
| 6. Steam Enthalpy at LP exhaust(Kcal/Kg) | : 581 | 583.5 | 586 | 590 | 595 |
| 7. Drains & vents Flow to ACC(T/Hr) | : 355 | 358 | 362 | 368 | 376 |
| 8. Avg. enthalpy of Drains & vents (kcal/kg) | : 215 | 234 | 237 | 252 | 276 |
| 9. Site Elevation from MSL(m) | : 611 | 611 | 611 | 611 | 611 |
| 10. Design Temperature | : | -----As per HEI----- | | | |
| 11. Condensate Flow at outlet of ACC (T/Hr) | : 1506 | 1518 | 1535 | 1562 | 1596 |
| 12. Heat Load (calculated)(Kcal/hr) | : 663176×10^3 | 675869×10^3 | 684088×10^3 | 700341×10^3 | 722425×10^3 |
| 13. Distance of TG centerline to TG column Towards ACC (m) | : 14 | 14 | 14 | 14 | 14 |
| 14. CW Inlet temperature for Heat Exchanger of Vacuum Pump (Deg C) | : 33 | 33 | 33 | 33 | 33 |
| 15. Seismic acceleration | : | -----0.19g horizontal----- | | | |
| 16. Noise limit (dB) | : | ----- 85 ----- | | | |
| 17. Basic Wind Speed | : | ----- 39m/sec ----- | | | |

- Note:-1. 5% margin on area to be considered for each case. Fouling resistance to be considered as per HEI.
2. Bidder to furnish the achieved back pressure corresponding to worst ambient air temperature considering designed ambient temperature as specified above.

1. Condenser

| | | | |
|---|-------------------|--|-------|
| Direct air cooled, forced circulation type | | | |
| Design, manufacture and testing code |  |  | ..... |
| ii) Heat load considered for design (with reference of corresponding heat balance diagram) |  |  | ..... |
| iii) Design air flow quantity with inlet temp. of 38 de. C and 42 Deg C |  |  | ..... |
| iv) Vacuum in the condenser with ambient air temp. of 38 deg. C and 42 Deg. C. | mmHg (abs) |  | ..... |
| v) Tube outside diameter and thickness | mmxmm |  | ..... |
| vi) Tube material |  |  | ..... |
| vii) No. of cells (Fin-tube assemblies) |  |  | ..... |
| viii) Steam duct material from turbine exhaust to ACC |  |  | ..... |
| ix) Air cooled condenser (ACC) design pressure | Kg/cm2 (gauge) |  | ..... |
| x) Air cooled condenser (ACC) test pressure | Kg/cm2 |  | ..... |
| xi) ACC header material thickness | mm |  | ..... |
| xii) Corrosion allowance | mm |  | ..... |
| xiii) Header material |  |  | ..... |
| xiv) No. of rows / streets nos. |  |  | ..... |
| xv) Corrosion allowance | mm |  | ..... |
| xvi) Tube plate thickness | mm |  | ..... |
| xvii) Corrosion allowance for tube plate | mm |  | ..... |
| xviii) Tube plate material |  |  | ..... |
| xix) Design velocity through tubes | m/sec |  | ..... |
| xx) Pressure drop across tube /cells of condenser on steam side | mwc |  | ..... |
| (Furnish back-up calculations& data on provenness) | | | |
| xxi) Total heat transfer surfacearea | sq.m |  | ..... |
| xxii) Overall heat transfer coefficient | Kcal/hr/ m2/deg C |  | ..... |
| xxiii) Number of tubes/ panels / cells which can be plugged without affecting condenser performance |  |  | ..... |
| xxiv) Rated ITD | | | |
| a) Design value | deg C |  | ..... |
| b) 42 deg. C | deg C |  | ..... |
| xxv) Weight of ACC | | | |
| a) Empty | Tonnes |  | ..... |
| b) Operating condition | Tonnes |  | ..... |
| xxvi) Method of supporting ACC |  |  | ..... |
| xxvii) Type of steam duct to LP turbine casing joint |  |  | ..... |
| xxviii) Material of expansion joints used in the steam duct |  |  | ..... |
| xxix) Provision for compensating thermal expansion of condenser |  |  | ..... |
| xxx) Type of exhaust steam duct Removable / Non-removable |  |  | ..... |
| xxxi) Maximum oxygen content in the condensate leaving the condensate tank (Furnish write-up on how deaeration of make up water is done) |  |  | ..... |
| a) under normal condition |  |  | ..... |
| b) under abnormal condition |  |  | ..... |
| xxxii) Condensate tank storage capacity between the normal water leveland low water level | cu. m |  | ..... |
| xxxiii) Condenser pressure during bypass operation | Kg/cm2(abs) |  | ..... |

- xxxiv) Steam throw off device
 - a) Capacity T/hr
 - b) Number of nozzles
 - c) Total no. of devices (per condenser)

2. Condenser Air evacuation system(vacuum pumps)

for Main Drive turbine
Condenser

- a) Make & Model
- b) Number offered
- c) Number working
- d) Size and type
- e) Design code
- f) Capacity in free air delivered at standard conditions with pump operating at saturated inlet condition of 25.4 mm Hg (abs) & at design condenser pressure & sub-cooled by 4.17 deg. C below temperature corresponding to the absolute suction pressure scfm
 - i)
(at 25.4 mm Hg (abs))
 - ii)
(at Design condenser pressure)
- g) Capacity of each pump during hogging operation at 10" (254 mm) Hg (abs) suction pressure scfm
- h) Suction Pressure mm Hg (abs)
- i) Suction temperature at
 - i) 25.4 mm Hg (abs) suction pressure deg C
 - ii) 196 mm Hg (abs) suction pressure deg C
- j) Suction line pressure drop mm Hg
- k) Power required at pump
 - i) 25.4 mm Hg cond. pressure kW
 - ii) Condenser design pressure kW
- l) Sealing water for vacuum pump and Cooling water required for sealant heat exchanger Cu.m/hr
- m) Design ITD (Saturation temperature cooling water inlet temp.) deg. C
- n) Design TTD of heat exchanger deg C
- o) Volume of condenser and turbine steam spaces to be evacuated as a basis of pump design cu.m
- p) Time to evacuate the above volume under standard conditions (21.1 deg C & 1.033 (abs)) minutes
- q) Whether air ejector is provided Yes/no
- r) Number of stages
- s) Compression ratio of each stage
- t) Cooling water pressure at inlet to heat exchanger
- u) Blank off suction pressure(at 36 deg. C cooling water inlet temp.) mmHg
- v) Motor
 - i) Make
 - ii) Rating kW
 - iii) Rated voltage kV
- w) Weight of each pump motor unit Tonnes

- x) Material of pump
 - i) Casing
 - ii) Shaft
 - iii) Impeller
 - iv) Shaft Sleeves
 - v) Cooler tubes
- y) Characteristic/Performance curves
(without air ejector and with air ejector, if applicable) :
 - i) Inlet air capacity in free dry air vs. suction pressure for ITD values of 10 deg. C, 11 deg C, 13 deg C, 15 deg. C & 16 deg. C
 - ii) Power consumption vs. suction pressure
 - iii) Suction pressure vs. sealant temp./ITD showing air ejector cutting in and cutting off (if applicable)
 - iv) Pump performance with and without air ejector (if applicable) for different back pressures and condenser heat loads
 - v) Air evacuation time(hogging time) vs. pump suction pressure with one pump in operation and two pumps in operation.
 - vi) Design Air leakage into the cond. considered for sizing the condenser air evacuation system

3. CONDENSATE EXTRACTION PUMPS(PER UNIT)

- 1.00 Design flow rate (kg/hr)
- 2.00 **Design inlet condition**
- 2.01 Inlet temp. (deg.C)
- 2.02 Specific gravity
- 2.03 NPSH required at impeller centre line
- a) 3% head breakdown m
- b) 1% head breakdown m
- c) 0% head breakdown m
- d) 40,000 hrs. erosion life of first stage impeller m
- 3.00 **Design discharge conditions**
- 3.01 Discharge pressure ata
- 3.02 TDH m
- 3.03 Shut off head m
- 4.00 Pump speed rpm
- 5.00 **Power Consumption at design Condition**
- 5.01 Power input to motor at 50 Hz/47.5 Hz kW
- 5.02 Loss in motor at 50 Hz/47.5 Hz kW
- 5.03 Power input to pump at 50 Hz/47.5 Hz kW
- 5.04 Efficiency of pump alone, %
- 5.05 Overall efficiency of pump set %
- 6.00 Suction Specific speed for first stage indicating the flow at which US Units the same is considered
- 7.00 Cannister losses mwc
- 8.00 Seal water requirement(flow/pressure/temp.)cu.m/hr./ata/°C
- 9.00 Minimum flow for continuous stable

| | | |
|--|-------------------|-------|
| operation | cu.m/hr | ..... |
| 10.00 On set recirculation flow | cu.m/hr | ..... |
| 11.00 Peripheral speed at the eye of first stage impeller, | m/sec | ..... |
| 12.00 Maximum thrust, up/down | Kgs | ..... |
| 13.00 Manufacturer |  | ..... |
| 14.00 Model Number and No. of pumps |  | ..... |
| 15.00 Number of stages |  | ..... |
| 16.00 Type of first stage impeller |  | ..... |
| 17.00 Impeller outer diameter, | mm | ..... |
| 18.00 Suction specific speeds US units |  | ..... |
| 19.00 Design pressure of bowl and discharge components, | ata | ..... |
| 20.00 Outer casing (can) : | | |
| 20.01 Minimum wall thickness, | mm | ..... |
| 20.02 Design pressure | ata | ..... |
| 20.03 Depth below pump mounting flange | mm | ..... |
| 21.00 Suction connection: | | |
| 21.01 Size/schedule |  | ..... |
| 21.02 Type of connection with piping |  | ..... |
| 21.03 Depth of centerline below pump mounting flange | mm | ..... |
| 22.00 Discharge connection: | | |
| 22.01 Size/schedule |  | ..... |
| 22.02 Type of connection with piping |  | ..... |
| 22.03 Height of centerline above pump mounting flange | mm | ..... |
| 23.00 Critical speeds: | | |
| 23.01 First critical speed in water | rpm | ..... |
| 23.02 Second critical speed in water | rpm | ..... |
| 24.00 GD ₂ of rotor including coupling | kg-m ² | ..... |
| 25.00 Impeller shaft: | | |
| 25.01 Length | mm | ..... |
| 25.02 Dia | mm | ..... |
| 25.03 Span between bearings, | mm | ..... |
| 26.00 Intermediate shafts: | | |
| 26.01 Length | mm | ..... |
| 26.02 Dia | mm | ..... |
| 26.03 Span between bearings (max.) | mm | ..... |
| 26.04 Method of coupling with adjacent shafting. |  | ..... |
| 27.00 Radial bearings | | |
| 27.01 Type & Number |  | ..... |
| 27.02 Size | mm | ..... |
| 28.00 Thrust bearing | | |
| 28.01 Located in pump/motor |  | ..... |
| 28.02 Type & number |  | ..... |
| 28.03 Design load, | kg | ..... |
| 28.04 Max. load | kg | ..... |
| 29.00 Bearing lubrication type: | | |
| 29.01 Radial bearing |  | ..... |
| 29.02 Thrust bearing |  | ..... |
| 29.03 Recommended hole size of suction strainer |  | ..... |
| 30.00 First stage details | | |
| (Bidder shall necessarily fill up this data) | | |
| 30.01 Impeller eye diameter mm |  | ..... |
| 30.02 Hub diameter mm |  | ..... |
| 30.03 Inlet angle degrees |  | ..... |
| 30.04 Inlet area between vanes normal to average Meridional velocity | sq.mm | ..... |
| 30.05 Eye, peripheral velocity | M/sec. | ..... |

| | |
|--|---------|
| 30.06 Axial fluid velocity, in eye | M/sec. |
| 30.07 Discharge angle | Degrees |
| 30.08 Discharge area between vanes normal to average meridional velocity | sq.mm |
| 30.09 Width of impeller water way at discharge | sq.mm |
| 30.10 Impeller eye area | sq.mm |
| 30.11 Impeller/diffuser width ratio | |
| 30.12 Number of impeller vanes | |
| 30.13 Clearance between impeller tip and diffuser | % |
| 31.00 Pressure pulsation data (peak-to-peak) | |
| 31.01 At suction and discharge nozzle : | |
| - design, flow metres | |
| - b.e.p. metres | |
| - 60% flow metres | |
| - 40% flow metres | |
| - Minimum flow metres | |
| 31.02 Maximum allowable metres | |

4. DRIP PUMPS(PER UNIT)

| | | |
|--|-----------------|-------|
| 1.00 Design flow rate | (kg/hr) | ..... |
| 2.00 Design inlet condition | | |
| 2.01 Inlet temp. | (deg.C) | ..... |
| 2.02 Specific gravity |  | ..... |
| 2.03 NPSH required at impeller centre line |  | ..... |
| a) 3% head breakdown | m | ..... |
| b) 1% head breakdown | m | ..... |
| c) 0% head breakdown | m | ..... |
| d) 40,000 hrs. erosion life of first stage impeller | m | ..... |
| 3.00 Design discharge conditions | | |
| 3.01 Discharge pressure | ata | ..... |
| 3.02 TDH | m | ..... |
| 3.03 Shut off head | m | ..... |
| 4.00 Pump speed | rpm | ..... |
| 5.00 Power Consumption at design Condition | | |
| 5.01 Power input to motor at 50 Hz/47.5 Hz | kW | ..... |
| 5.02 Loss in motor at 50 Hz/47.5 Hz | kW | ..... |
| 5.03 Power input to pump at 50 Hz/47.5 Hz | kW | ..... |
| 5.04 Efficiency of pump alone, | % | ..... |
| 5.05 Overall efficiency of pump set | % | ..... |
| 6.00 Suction Specific speed for first stage indicating the flow at which US Units the same is considered |  | ..... |
| 7.00 Cannister losses | mwc | ..... |
| 8.00 Seal water requirement(flow/pressure/temp.) | cu.m/hr./ata/°C | ..... |
| 9.00 Minimum flow for continuous stable operation | cu.m/hr | ..... |
| 10.00 On set recirculation flow | cu.m/hr | ..... |
| 11.00 Peripheral speed at the eye of first stage impeller, | m/sec | ..... |
| 12.00 Maximum thrust, up/down | Kgs | ..... |
| 13.00 Manufacturer |  | ..... |
| 14.00 Model Number and No. of pumps |  | ..... |
| 15.00 Number of stages |  | ..... |
| 16.00 Type of first stage impeller |  | ..... |
| 17.00 Impeller outer diameter, | mm | ..... |
| 18.00 Suction specific speeds US units |  | ..... |
| 19.00 Design pressure of bowl and discharge components, | ata | ..... |

| | | |
|---|--|-------------------|
| 20.00 Outer casing (can) : | | |
| 20.01 | Minimum wall thickness, | mm |
| 20.02 | Design pressure | ata |
| 20.03 | Depth below pump mounting flange | mm |
| 21.00 Suction connection: | | |
| 21.01 | Size/schedule | |
| 21.02 | Type of connection with piping | |
| 21.03 | Depth of centerline below pump mounting flange | mm |
| 22.00 Discharge connection: | | |
| 22.01 | Size/schedule | |
| 22.02 | Type of connection with piping | |
| 22.03 | Height of centerline above pump mounting flange | mm |
| 23.00 Critical speeds | | |
| 23.01 | First critical speed in water | rpm |
| 23.02 | Second critical speed in water | rpm |
| 24.00 | GD ₂ of rotor including coupling | kg-m ² |
| 25.00 Impeller shaft | | |
| 25.01 | Length | mm |
| 25.02 | Dia | mm |
| 25.03 | Span between bearings, | mm |
| 26.00 Intermediate shafts | | |
| 26.01 | Length | mm |
| 26.02 | Dia | mm |
| 26.03 | Span between bearings (max.) | mm |
| 26.04 | Method of coupling with adjacent shafting. | |
| 27.00 Radial bearings | | |
| 27.01 | Type & Number | |
| 27.02 | Size | mm |
| 28.00 Thrust bearing | | |
| 28.01 | Located in pump/motor | |
| 28.02 | Type & number | |
| 28.03 | Design load, | kg |
| 28.04 | Max. load | kg |
| 29.00 Bearing lubrication type | | |
| 29.01 | Radial bearing | |
| 29.02 | Thrust bearing | |
| 29.03 | Recommended hole size of suction strainer | |
| 30.00 First stage details | | |
| (Bidder shall necessarily fill up this data) | | |
| 30.01 | Impeller eye diameter | mm |
| 30.02 | Hub diameter | mm |
| 30.03 | Inlet angle degrees | |
| 30.04 | Inlet area between vanes normal to average Meridional velocity | sq.mm |
| 30.05 | Eye, peripheral velocity | M/sec. |
| 30.06 | Axial fluid velocity, in eye | M/sec.2 |
| 30.07 | Discharge angle | Degrees |
| 30.08 | Discharge area between vanes normal to average meridional velocity | sq.mm |
| 30.09 | Width of impeller water way at discharge | sq.mm |
| 30.10 | Impeller eye area | sq.mm |
| 30.11 | Impeller/diffuser width ratio | |
| 30.12 | Number of impeller vanes | |
| 30.13 | Clearance between impeller tip and diffuser | % |
| 31.00 Pressure pulsation data (peak-to-peak) | | |
| 31.01 | At suction and discharge nozzle : - design, flow | metres |

| | |
|-------------------------|--------|
| - b.e.p. | metres |
| - 60% flow | metres |
| - 40% flow | metres |
| - Minimum flow | metres |
| 31.02 Maximum allowable | metre |

AUXILIARY POWER CONSUMPTION

| Sl. No. | Name of the Equipment | No. off per set | No. off in run | Rated Power (KW) | Total Power consumption (KW) | Remark |
|--------------------------------------|--|-----------------|----------------|------------------|------------------------------|--------|
| Condenser and Heat Exchangers | | | | | | |
| | | | | | | |
| | ACC(below mentioned) | | | | | |
| 1 | Fan& Motor | | | | | |
| 2 | CEP (including recirculation pump) 3 x 50% | | | | | |
| 3 | Drain pump 2x100% | | | | | |
| 4 | Vacuum Pump (2X100%) | | | | | |
| 5 | Hogging Pump (1X100%) | | | | | |
| 6 | Other Equipments | | | | | |