Mapping of 85 pulverized coal fired thermal power generating units in different states (Under Indo-German Energy Program (IGEN))

FOREWORD

The Power Plant Component of India German Energy Programme (IGEN) is being implemented in India with the cooperation of Central Electricity Authority (CEA), Ministry of Power, Government of India and GTZ, Germany. The overall aim of this programme is to support and prepare public plant operators for performance reporting as well as implementation of financially attractive and technically viable improvements of power plant net heat rate.

Under the IGEN programme, mapping of 85 coal based power generating units, ranging from 100 to 500 MW capacities, were carried out by using a diagnostic tool. This study has been completed during the period 2007-09 covering state owned plants in 14 States, 17 power utilities and 45 thermal power stations. The mapping studies have been done on two conditions namely design parameter as well as on actual operating parameters gathered from different plants for a specific period. The unique feature of this study is that heat rate of the generating unit is not based on the quantification of coal consumed and energy generated but with the thermo dynamic balancing of actual operating parameters.

The primary purpose of mapping study is to provide a data base and broadly identify areas requiring attention for improving energy efficiency. The baseline mapping provides an objective method of setting targets and monitoring progress. The reports provide an indication about the necessity and urgency of taking up detailed Residual Life Assessment studies and Renovation & Moderation (R&M) measures in some of the plants. The report, also, indicates measures that could be taken up immediately with comparatively smaller expenditure to improve plant performance before going in for regular R&M measures.

The outcome of the study was discussed with the individual State Utilities, who appreciated the recommendations made and findings of the study. Some of the utilities have already implemented majority of the recommendations and others are in process of implementing.

For wider dissemination of the findings of the mapping study, the report is being uploaded on CEA website for the benefit of power stations where the mapping study was not carried out. The report highlights the major deviations in operation from design parameters and measures suggested to improve the performance of the plants. The power station personnel may implement the recommendations of the mapping studies to improve the performance of their plants.

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SUMMARY REPORT

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SUMMARY OF EBSILON MAPPING AND MODEL ANALYSIS OF 85 PULVERIZED COAL FIRED THERMAL POWER GENERATING UNITS IN DIFFERENT STATES

1.0 INTRODUCTION

The Ministry of Power, Government of India, and Deutsche Gesellschaft fur Technische Zusammenarbeil (GTZ) Gmbh signed an 'implementation agreement' with respect to the Indo-German Energy Programme (IGEN) in the year 2006. Under the IGEN agreement, power plant component is being implemented by the Central Electricity Authority (CEA), in association with the Bureau of Energy Efficiency (BEE), for performance optimization and efficiency improvements of thermal power plants. The programme aims to support and prepare power plant operators for performance reporting as well as implementation of financially attractive and technically viable improvements of power plant net heat rate under the provisions of the Energy Conservation Act.

The project is being executed under two main sub-components:

(i) Mapping studies of thermal power generating units and,

(ii) Performance optimization of thermal power stations.

Under the first phase of the programme, GTZ provided support to Central Electricity Authority (CEA) for creating data base of the older thermal power plants in India. The scope of the work primarily covers the mapping of 85 thermal power generating units using Ebsilon software.

The mapping has been done for two conditions, namely for design parameters and for the actual operating status for the plant parameters gathered from different plant locations. The primary purpose is to provide a database within CEA and broadly identify areas needing attention in the short, medium and long term for improving energy efficiency. The baseline mapping provides an objective method of setting targets and monitoring progress.

Evonik Energy Services India (EESI) was appointed to carry out the mapping of the 85 power generating units. EESI is a 100% owned subsidiary of Evonik Energy Services GmbH Germany. Evonik, Germany, owns and operates a number of large coal fired power plants with an installed capacity of 11,000 MW in Germany and other countries.

The identified mapping studies of 85 units ranging in capacity from 100 MW to 500 MW each were completed during the period 2007-09 in 14 Indian States viz Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Jharkhand, Madhya Pradesh, Karnataka, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. These units are part of 45 thermal power stations owned by 17 Power Utilities. The numbers of selected units of different capacities are shown in Table 1 while details of owning utility, name of power station and capacity of unit selected for mapping are depicted in Annexure 1.

Table 1 – Capacities of Selected Units

Capacity (MW)	Number of Units
100	1
105	1
110	6
120	8
125	1
140	4
195	1
200	4
210	49
250	5
500	5
Total	**85**

2.0 MAPPING PROCEDURE

Project teams comprising engineers from CEA and Evonik Energy Services were constituted for groups of units to ensure expert contribution in the mapping studies and in analysis. A nodal officer of the owning utility was nominated at each plant to assist and provide data to the project team. The team visited the unit and discusses and physically checked the condition of the unit. The major observations were discussed and incorporated in the model.

3.0 METHODOLOGY

Design and current operating data for the units were obtained through questionnaires sent by CEA to concerned utilities. Further required data were collected during site visits by Evonik engineers. A design model was then built on the basis of design data obtained from site using Ebsilon software. Actual operating parameters were obtained from site and the design model was adjusted to create an operating model based on the current condition of environment and status of the machine. Simulations were then done using the actual coal and the design coal data.

4.0 FINDINGS

The mapping studies revealed that most of the units are being operated under various constraints like poor quality of coal, poor spare and activity planning, turbine and other equipments, Poor condenser vacuum, high steam consumption, poor housekeeping, operating parameters different from the rated values and obsolete instrumentation. These have resulted in high heat rates and unreliable plant operations. These observations are analyzed below.

5.0 ANALYSIS OF OBSERVATIONS

The gross heat rate values as well as other operating indices for all the 85 generating units have been tabulated for different unit sizes in Annexures 2A to 2G.

Analysis of important power plant performance indicators namely gross heat rate, turbine heat rate, boiler efficiency and auxiliary power consumption has been carried out for the same size of units (100-110 MW, 120-125 MW, 140 MW, 195-200 MW, 210 MW, 250 MW and 500 MW). The comparative unit wise position for the above indices is shown in Annexures 3A to 3P.

5.1 Heat Rate Variations

The average design and operating values of gross heat rate as also the percentage deviation for each group size is given in Table 2 below:

Table 2 – Gross Heat Rate Deviations

Capacity range of units	No. of units	Average Design Gross Heat Rate (kcal/kWh)	Average Operating Gross Heat Rate (kcal/kWh)	Average deviation (%)	Range of operating GHR (kcal/kWh)
100-110 MW	8	2413.3	2994.4	24.1	2696 - 3601
120-125 MW	9	2415.4	2894.5	19.8	2690 - 3730
140 MW	4	2381.7	2822.9	18.5	2750 - 2905
195-200 MW	5	2385.7	2873.6	20.5	2393 - 3962
210 MW	49	2408.3	2765.8	14.8	2384 - 3064
250 MW	5	2300.6	2685.6	16.7	2546 - 2773
500 MW	5	2254.6	2561.3	13.6	2508 - 2647

*Heat Rate calculated using the design & operating model

Since the operating heat rates recorded were very high in smaller capacity units compared to higher capacity units, this is because of the development metallurgy and in turbine design. Even the variation found higher in 195-200 MW units and most of the unit except one are very old units and these units require the mega R&M and use the latest technology and up gradation and replace the obsolete technology.

The variations in turbine heat rates are depicted in Table 3 below.

Table 3 - Turbine Heat Rate Variations

Capacity range of units	No. of units	Average Design Turbine Heat Rate (kcal/kWh)*	Average Operating Turbine Heat Rate (kcal/kWh)*	Average Deviation (%)	Range of operating THR
100-110 MW	8	2134.4	2356.3	10.4	2215 - 2881
120-125 MW	9	2081.0	2314.6	11.2	2162 - 2796
140 MW	4	2054.0	2279.4	11.0	2243 - 2325
195-200 MW	5	2051.9	2305.8	12.4	2033 - 2893
210 MW	49	2024.3	2166.1	7.0	2045 - 2442
250 MW	5	2001.2	2239.2	11.9	2179 - 2274
500 MW	5	1976.4	2108.3	6.7	2087 - 2179

*Heat Rate calculated using the design & operating model.

The tabulation of operating indices for individual units in the above seven capacity ranges in Annexures 2A to 2G indicates that in each category there are a few units which are operating quite close to their design heat rates. For example, in the 210 MW categories, out of the 49 units for which operating data is available, there are 17 units for which operating heat rate is within 7.5% of the design heat rate. For 500 MW capacity, 4 units out of 5 units mapped have their operating turbine heat rate within 7.5% of design.

The analysis brings out, also, that deterioration in the turbine heat rate is the major factor for gross heat rate deterioration. For example, the weighted average deterioration of turbine heat rate came as 10% compared to the average gross heat rate deviation of 18 %

5.2 Variations in Boiler Efficiency

Table 4 depicts the variations in boiler efficiency observed in units of different sizes.

Table 4 – Boiler Efficiency Variations

Capacity range of units	No. of units	Average Design Boiler Efficiency (%)	Average Operating Boiler Efficiency (%)	Average Deviation (%)	Range of Operating Boiler Eff.
100-110 MW	8	86.9	80.5	7.4	78.8 – 82.3
120-125 MW	9	86.1	80.1	7.0	75.0 – 82.5
140 MW	4	85.9	80.7	6	80.0 – 81.5
195-200 MW	5	86	80.8	6.1	73.0 – 85.0
210 MW	49	85.8	81.7	4.8	71.0 – 86.0
250 MW	5	87.2	83.4	4.4	82.7 – 85.6
500 MW	5	87.7	82.3	6.1	79.0 – 84.1

*Boiler Efficiency calculated using the design & operating model

It is seen that boiler efficiencies are close to design values and variation is mainly due to variation from design parameters and combustion problems.

6.0 SAVINGS POTENTIAL IN COAL CONSUMPTION AND COST

Substantial savings in coal consumption and operational costs are possible with better maintenance and improvements in heat rate. The potential savings under two assumptions are shown below:

Assumption

Units operate at an average gross heat rate which deviates only by 7.5 % from the average design heat rate.

Table 5 below gives the potential savings in coal consumption and economy in cost if all the units of a particular capacity group operate at an average heat rate which deviates by 7.5% only from the average design heat rate as compared to the situation in which all the units in the group operate at the actual operating heat rate.

Assumptions:

Average calorific value of coal – 3626 kcal/kg

Price of coal – Rs 1400/ton

Average plant load factor (2008-09) – 77.2%

Table 5 – Savings with improvement in heat rate to within 7.5% of the average design heat rate

Unit size	No. of units	Heat rate 7.5% higher than design	Actual operating heat rate	Diff in heat rate	Savings in Coal "000 tons/yr		Savings in Money Rs crore/yr
MW	Nos.	kcal/ kWh	kcal/ kWh	kcal/ kWh	Sp coal saving/unit	Saving in coal	Overall cost
100-110	8	2594.3	2994.4	400.1	0.11	655.05	91.7
120-125	9	2596.5	2894.5	298.0	0.082	623.65	87.3
140	4	2560.3	2822.9	262.6	0.072	273.56	38.3
195-200	5	2564.63	2873.6	309	0.085	856.49	119.9
210	49	2588.97	2765.8	176.8.	0.049	3384.62	473.8
250	5	2473.1	2685.6	212.5	0.058	494.18	69.2
500	5	2423.7	2561.3	137.6	0.038	640.18	89.6
					Total	6927.7	969.9

*Heat Rate calculated using the design & operating model

Table 5 indicates that with improvement in heat rate of units to within 7.5 per cent of the design heat rate, as is normally accepted after R&M is undertaken for the units, saving of 6.92 million tons per year of coal can be expected for all the 85 units for which Ebsilon mapping studies were undertaken. This saving in coal could enable generation of about 9,600 MU per year if used in 500 MW units.

7.0 REASONS FOR HIGH OPERATING GROSS HEAT RATES

It is observed that the heat rate is very high in some units while in others it is only moderately high. Based on observations during site visit and discussions with the site engineers on the operation and maintenance aspects of the power plants, some areas commonly observed to be responsible for high operating gross heat rate are listed below. These observations are not applicable to all the units but are representative of the type of problems encountered. For specific sites, pertaining units , the individual reports may be referred to obtain more details. The simulations have been carried out considering the current condition of unit and its operating environment

Analysis of observations for different power plants indicates that the major reasons for the high operating gross heat rate are:

1 Low combustion efficiency lead to high carbon loss.
2 High force outages due to failure of boiler tubes.
3 Poor performance of milling system.
4 Lack of Maintenance planning and spare planning
5 Low turbine cylinder efficiency
6 High dry gas losses due to high unwanted excess air
7 Poor sealing and heat transfer in air pre-heaters
8 Low condenser vacuum.
9 High air ingress in the boiler and high heat loss due to poor insulation
10 Poor Performance of ESP lead to failure of ID fan and low availability.
11 High cooling water inlet temperature due to poor performance of CT
12 Improper mill maintenance due to non availability of grinding media.
13 Non availability of quantity and quality fuel.
14 High auxiliary power consumption due to high heat rate and outages.
15 Obsolete C&I system needs maximum manual controls lead to error.
16 Poor quality critical valves lead to passing and poor control
17 High Boiler corrosion and erosion lead to high force outage
18 Obsolete electrical relays and control lead to more force outage
19 Obsolete governing and excitation system unable to meet the grid demand variation of load

It must be observed that the significance of the above factors differs amongst different capacity ranges, as also, in between units of the same range. In general, the deviations from optimum are less for 250 MW and 500 MW units. One of the major cause for the unreliability is poor Housekeeping and equipment maintenance planning.

7.1 Un-optimized Boiler Combustion and High Excess air

In some of the units, the boiler is being operated without having the feedback based control of combustion air and new measurement of air-fuel ratio. There was a wide variation of fuel air ratio and quantity of secondary air and primary air .The other major attention is the air fuel velocity is not the same for all the coal burners. The unbalanced flame velocity leads poor flame profile in tangential firing system (mostly in operation in India) and change in temperature profile.

7.2 Low Turbine Cylinder Efficiency

The efficiency of HP, IP and LP turbine cylinders was mapped. It was observed that most of the turbines have much lower isentropic efficiency than design values .This is due to high seal clearances and salt deposits. This has affected the turbine heat rate.

7.3 Inefficient Soot Blowing of Boiler Tubes

Soot blowing is provided to clean the boiler tubes from the fire side deposits resulting from combustion of coal. The ineffective soot blowing leads to lower heat transfer to boiler tubes, wastage of thermal energy lead to higher exit flue gas temperatures which affect boiler efficiency adversely. We are not operating LRSB due to the earlier design defects. The modified LRSB and sonic soot blowers shown excellent results to maintain a clean boiler tube surface in second pass effectively.

7.4 Inefficient Air Pre-Heaters

Air pre-heater is important equipment which utilizes waste flue gas heat to pre-heat the cold combustion air. Low temperature inlet hot air to mills affect the coal drying and intern reduce the mill capacity.

Worn-out/choked heating elements, Improper seal clearances, damaged sector plates and side sealing plates, air ingress due to damaged expansion bellows improper sealing of inspection holes were observed for the poor air preheater efficiency .This also lead to increase the auxiliary power consumption by more power consumption of ID fan and PA and FD fan due to handling of high qty unutilized leakage air. In case of tubular air heater improper damaged ferruling and leaking tubes were recorded as the major causes

7.5 Low Condenser Vacuum

This act as a major factor for heat rate deterioration in india due to variation in air ingress and cooling water quality and quantity. It was observed that in some units, the condenser vacuum was lower by 3 to 5 percent from its design value. The vacuum in turn depends upon cooling water quantity, temperature and air ingress in the condenser. It was notices that heat rate increase due to low condenser vacuum which is 6 to 10 percent of the design value. Most places we do not have HP/LP by pass system working on auto and have capacity of only 30%

7.6 High Air Ingress in the Boiler.

The boiler is designed to fully safeguard itself against air ingress from external sources. The air ingress is the cause of over loading of the induced draft fan and also affects the boiler efficiency. It is observed that in many of the old units, particularly those of smaller sizes having refractory insulation, the ingress of air is very high- Oxygen mapping will clearly indicate the air ingress section and take the corrective action accordingly.

7.7 High Super-heater and Re-heater Spray

The boiler is designed for almost zero spray at full load with design coal. The spray is very high in some boilers due to poor coal quality. In some boilers we are controlling the reheater temperature by restricting flue gas qty in that section .This affects to divert more gas in superheater coil side and more heat pick up. To keep the metal temperature and steam temperature with in limit we use heavy attemperation in superheater side.

As the quantity of coal fired changes and qty of flue gas also changes and changes the flame profile. Due to the above variation heat distribution and heat transfer in different sections of boiler tubes changes and lead to rise in metal temperature. In some boiler we have observed metal oxide formation in reheater and superheater tubes due to overheating and restrict the heat transfer and lead to boiler tube failure.

7.8 Poor Vacuum &High Cooling Water Inlet Temperature

The cooling water temperature is high in those units where cooling towers are not well maintained. This results in poor vacuum and high heat rate. The Poor performance of circulating water pumps, choking of tubes due to debris, Non availability of any auto cleaning system also reduces the qty of CW flow and increases the CW outlet temp and poor vacuum. We have observed damaged flash tank, expansion bellows and poor gland sealing steam pressure, poor nozzles of ejectors also leads to cause poor vacuum in condenser.

7.9 Milling system output less than Design Value

In some of the 210 MW units, five mills have to be kept in operation instead of the provision of four mills at full load thus affecting availability of spare mill for maintenance. Most of the time, this problem is due to poor coal quality or poor maintenance of mill itself. Replacements of grinding material on time to get the rated output from mills were not practiced in some stations. Non availability of reliable gravimetric feeder further reduces the analysis and preventive action on time

7.10 Coal Quality not conforming to Design Coal

The boiler is designed to burn specified coal linked to a particular source having defined set of values for gross calorific value, volatile matter, moisture and ash content. It is observed that the quality of coal actually received at power plants was vastly different from that of the design coal. The mismatch in design and actual characteristics of coal is the cause of many of the maintenance and operational problems. Many power plants get coal with much lower gross calorific value which in turn is due to high ash content. The high ash content results in lowering boiler efficiency and erosion of boiler tubes leading to high outages and high wear and tear of milling and coal carrying system. Due to the high size of the coal neither station able to unload the coal nor able to handle the same. If we can bring the coal less than 5 mm, we can reduce the handling and transportation easy. Non availability of the coal is becoming one of the major partial outage of units.

7.11 High Auxiliary Power Consumption

The auxiliary power consumption is an important index to determine as how efficiently a plant is operating. The auxiliary consumption has been found to vary in the range of 8 to 15 percent. It is essential to reduce it to acceptable limits. The problems relate to poor turbine efficiency lead to high specific steam consumption and indirectly high specific coal consumption. To meet the high specific fuel demand lead to more milling operation and more air requirement and more ID fan power consumption. Many auxiliaries were found running at over load regimes due to air ingress, passing of valves and similar reasons.

The operation controllable parameters can reduce the auxiliary by 0.2 t0 0.3% for the best station 1% for worst case from the high-end and other reduction needs the investment and use latest development in technology.

7.12 High Boiler tube leakage due to internal corrosion

During the evaluation of the performance of the units we have observed lot of failure due to internal corrosion. During the deposit analysis one of the major causes of failure was copper deposition and poor water chemistry. Some of the latest units came after 1990 it was observed that copper alloys were not used in the condensate circuit and these types of failure were not reported.. Since the change in rise of copper cost stainless steel low thickness tubes also found economical and reliable. So in case of the mega R& M it should be considered on case to case basis.

8.0 MODEL ANALYSIS

The model analysis has been carried out to determine the degradation of performance of important equipment which can affect the overall plant performance and efficiency. HS (Mollier) diagrams has been plotted to assess the current condition of the turbines.

Ebsilon software has been used to simulate and frame models with the design and the operating parameters. The software enables assessment of impact of changes in some parameters over those on other related parameters. The thermodynamic cycle analysis balances in totality and we can access the impact of one system gain on the other system. Such changes include deviations in coal quality; change in environmental parameters, cooling water temperature has been assessed. The base model in each case was developed on the basis of design parameters. Thereafter actual operating parameters were obtained from site and put in the sub-profile of the design model to obtain the performance of the unit under current operational conditions and assess the deviations. Deviations in the following can be determined with the help of the model taking into account the impact of external factors and current condition of the plant after operation of so many running hours. Most units already crossed more than 100,000 running hour's needs immediate attention to retain the following parameters within the best possible limits. In some cases it was already crossing the limits that require immediate R&M.

- Gross heat rate
- Turbine heat rate
- Boiler efficiency
- Unit efficiency
- Efficiency of HP turbine
- Efficiency of IP turbine
- Efficiency of LP turbine
- Regenerative heater performance
- Condenser performance
- Impact of exit flue gas temperature
- Coal quality deterioration

9.0 RECOMMENDATIONS AS PROPOSED IN THE MAPPING STUDIES

Recommendations to improve the performance and efficiency of the plant have been made for each of the units covering maintenance and operational aspects. These recommendations take into account the observations of Evonik experts at site, discussions with project engineers and deviations in operating parameters determined by Ebsilon mapping. The recommendations have been divided into three categories namely:

- Short term
- Medium term
- Long term

The short term recommendations are those which can be implemented immediately at a low cost. These relate to improving vacuum, mill operation, boiler operation, ESP (better housekeeping, on time deashing to avoid ash carry over and electrical maintenance) etc and all other equipment and systems as are considered important for improvement of plant efficiency.

The medium term recommendations pertain to those works which can be taken up during major shut down or during overhauling. These recommendations relate to attending to coal firing system, air dampers, flue gas system, cooling towers etc and other major defects observed by Evonik engineers.

The long term recommendations cover renovation and modernization aspects of the plant considering the available poor quality coal for power generation. Retrofitting the latest technology solutions for energy efficiency and increase in capacity, close loop auto controls to operate the plant with less manpower remotely, high quality material boiler tubes to operate continuously at high metal temperature and reduce the weight due to high stress limits, capsule turbines, EHS system, HP heaters, energy efficient cartridges for BFP, zero leak valves, SWAS system, new design condensers with stainless steel tubes and ATRS and 60% HP/LP bypass valves, vacuum pumps and energy efficient variable pitch axial fans, maintenance free metallic rotary gravimetric feeders Advanced grinding material to ensure reliable guaranteed operation. Numerical control relays, new switch gears Advanced DVRs, energy efficient motors VVF drives, VAM system for HVAC system by utilizing the waste heat after APH. Advanced ESP to meet the environmental STDs. These recommendations, however, will need further detailed studies which could be taken up at the stage of Residual Life Assessment, Renovation and Modernization and Life Extension studies.

10.0 INADEQUACIES IN OPERATION AND MAINTENANCE

The studies conducted on 85 units of thermal plants and interactions with project staff have indicated a number of inadequacies in operation and maintenance. These inadequacies are caused due to insufficiency of funds available for maintenance, a very poor spare planning and poor housekeeping and lack of predictive maintenance lead high Break down maintenance and non availability of equipments. Non availability of condition based routine maintence lead to high outages. Lack of training and non availability of documents lead to high outage time during the Breakdown jobs. Deficiencies commonly noticed for major plant components are noted below. The O&M team needs to be trained to meet the latest operational need of the station.

10.1 Boiler And Accessories

- Maintaining the Air-fuel mixture as per available coal.
- Poor pulverized coal fineness and qty to ensure optimum combustion.
- High excess air and flue gas qty at ID fan lead to reduce the operating margin.
- Poor ESP and ash collection system to meet the statuvatory requirements.
- Poor insulation leaking ducts and expansion joints lead to high radiation losses and heat losses.
- Poor water chemistry and copper deposition on boiler tubes lead to high boiler tube failures.
- Non availability of gravimetric feeders.
- Poor performance of burner tilt and secondary dampers, fuel and air control outstanding to obsolete C&I system.
- Poor penthouse sealing and totally filled with hot ash.
- Non replacement of grinding media on time lead to high specific power consumption and wastage of coal
- Poor house keeping
- Obsolete C&I system with minimum close loop controls
- Vent valves needs replacement
- No grid measurement of Oxygen and CO at economizer outlet.
- Oxide scale formation in superheater and reheater tubes due to high boiler tube metal temperature
- Damaged hangers and supports lead to vibration
- Poor condition of critical valves and vent valves lead to high DM consumption.

10.2 Turbine

- Obsolete and inefficient blades needs replacement can able to generate more power.
- High Nozzle losses and Poor inlet parameters of the turbine
- High sealing losses lead to due to poor efficiency and output.
- Obsolete Governing system and control valves not allow to operate the unit on frequency modulation mode.
- Obsolete Turbo supervisory system and protection needs replacement.
- Poor gland sealing and Brg housing and pedestal lead to restriction in expansion and vibration problems and lub oil leakages
- High air ingress into system due to pedestal oval and parting plane leakages and poor glands.
- Gland steam pressure control failure lead to high temperature and damage of oil guards and moisture ingress into lub oil system.
- Poorly maintained ATRS system
- Non working and low capacity Hp/Lp by pass valves on auto leads to more unit trips in emergency.
- Frequent failure of condenser tubes and in efficient ejectors,
- Poor steam quality lead to high deposition and pressure drop across the stages.
- Poor maintained deaerator lead to high dissolved oxygen
- Poor regenerative heaters lead to high DCA and less output.
- Poor Turbine insulation
- Poorly maintained lub oil quality and high consumption.

10.3 Condenser & cooling tower

- Online cleaning system not installed in many stations
- Debris filter not provided
- High air ingress and high dissolved oxygen in condensate.
- Leakage in expansion bellows and flash tanks
- Traveling water screen and back washing system not available
- Poor water quality lead to corrosion and pitting on base plates
- High copper carry over lead to copper deposition in Boiler
- High inlet cooling water temperature due to poor CT

10.4 C&I system

- The C&I systems at most of the plants are of older versions which become obsolete needs replacement by new DCS system

11.0 SYSTEM IMPROVEMENTS SUGGESTED

Experience of study and interaction with project personnel at power plants spread all over the country suggest that substantial improvements in their performance are feasible with improvements in management systems. These are indicated below which may be analyzed from case to case.

- Each unit should have a "Performance Monitoring schedule all Major systems in power plant including the auxiliaries (Coal handling plant, ash handling plant, water treatment plants and compressors). Monthly performance tests should be conducted to evaluate boiler efficiency, condenser performance, turbine cylinder efficiency, LP/HP heater performance, turbine heat rate etc. These figures should be checked with the design, last month's performance, best performance of the unit and best performance of similar other units in the station.
- Milling system maintenance and air preheater maintenance should be given the top priority based on the performance monitoring parameters and ensure timely replacement of worn out parts to ensure reliable output.
- Grid monitoring of Oxygen and CO to ensure a complete combustion and control combustion air to limit the dry gas losses.
- Installation of reliable rotary gravimetric feeders to ensure the coal quantity feed into the mill and indirectly to boiler to get an online assessment of boiler performance.
- Major maintenance of CW system and cooling towers to achieve quality and quantity of water, a clean condenser tubes to achieve better heat transfer and possible vacuum to gain maximum output.
- Up gradation of C&I system to replace the obsolete technology and installation of more close loop controls to avoid manual interference.
- Retrofitting of Electro hydraulic control system with auto starting of turbine system with motorized drains to meet the new grid codes and fast response to variation in demand and auto operation,
- Shift wise monitoring of operating controllable parameters and merit order operation concept to gain efficiency and availability.
- The results of monthly performance monitoring of the station should be discussed in a meeting taken by the Head of the plant and remedial action plan including action on urgent financial issues, should be decided in the meeting.
- Provision of computer software for performance monitoring, maintenance planning and for simulation studies at the plant site may be considered.

Spare planning and inventory management tools to be incorporated to avoid the delay in maintenance duration and non availability of spares.

- Annual overhaul of units and auxiliaries should be done regularly based on the performance deterioration. Assessment to be made before and after to access the techno economical gain as far as possible. Activities to be planned as far as possible on account of system demands.
- Manufacturer's maintenance manuals for different equipments and operating guide lines should be available in plant office. Senior officers during their inspections should ascertain that the instructions of the manuals are being followed.
- Retrofitting energy efficient hydro drive system for conveyors more than75 KW capacity
- Important work instructions pertaining to particular equipments should be displayed close to the equipment at an appropriate place.
- CFD modeled ducts to reduce the duct pressure losses and implementing VVF drives to reduce the auxiliary power consumption to be incorporated to update the unit performance to meet the latest demands.
- Retrofitting dry rotary compressors with HOC (heat of compressor for regeneration) drier in place of old compressors to maintain better instrument air and service air to meet the modern pneumatic instruments.
- Retrofitting the latest development in purification like RO system etc to make quality DM water from the deteriorated input water available.
- Retrofitting the dry bottom ash system with recirculation to reduce the water consumption and utilization of bottom ash.
- Charging the auxiliary header from CRH at rated load condition to reduce the energy loss of conversion to low pressure steam.
- Utilizing the waste heat to retrofit the VAM (Vapor absorption machines) refrigeration system in place of HVAC system.
- Energy efficient lighting system to utilize the latest LEDs to reduce the life cycle cost.
- One of the major causes for the poor performance is the poor housekeeping which needs immediate attention and close monitoring by top management. It has already proven that this will reduce the maintenance cost and increase the availability.
- Establishing a separate company at loading point or a centralized location (coal conditioning company) to condition or blend the coal and supply the proper size coal (1mm to 5mm size) in ensured quality (without stones and controlled calorific value and ash content) can reduce the losses to minimum and reduce the auxiliary power consumption . They can do the blending and first grinding and separation; This Company can

utilize the low calorific reject coal in the low capacity CFBC/PFBC technology and meet the heat and power requirement for coal conditioning. This will ensure reliability and availability of high capacity most efficient units and reduce the partial and force outage to minimum. Major partial outages were observed due to variation and non availability of coal for bigger capacity high efficiency units. This will reduce the high quality grinding media consumption and outage of high capacity units.

12.0 CONCLUSION

The mapping exercise of the 85 power plants has generated a lot of data and information on the performance of power plants. The reports have been sent to respective plant authorities and presentations have been made before the top managements at the respective utility headquarters. The reports provide an indication about the necessity and urgency of taking up detailed RLA / CA studies and R&M measures in some of the plants. The reports, also, indicate measures that could be taken up immediately with comparatively small expenditure to improve plant performance before going in for regular R&M measures.

The improvement in heat rate of units to within 7.5 per cent of the design heat rate, as is normally accepted after R&M is undertaken for the units, results in expected saving of about 6.93 million tons of coal per year for all the 85 units for which Ebsilon mapping studies were undertaken. This saving in coal could enable generation of about 9,600 MU per year if used in 500 MW units.

It has been observed, also, that in addition to the plant problems explained above, there is need to give attention to improved maintenance practices, manpower planning, training of engineers, installation of, preferably, on-line monitoring system and updating of auto controls and instrumentation. The use of computers for maintaining plant history records should be more extensive. It is necessary to carry out total audit of plant functions covering management issues, delegation of powers and inventory management which are equally important to improve the plant performance. The institutional arrangements require the establishment of an energy efficiency cell at each power plant location. The concept of Model Power Plant has been suggested by CEA to sustain the benefits of the mapping exercise.

ANNEXURE-1

Report No	State Board/ Electricity Gen. Company	Power Station	Unit size
1	PSEB	Guru Nanak Dev Thermal Power Station, Bathinda	110
2	MAHAGENCO	Khapar Kheda Thermal Power Station	210
3	WBPDCL	Kolaghat Thermal Power Station	210
4	TNEB	Mettur Thermal Power Station	210
5	MAHAGENCO	Nasik Thermal Power Station	210
6	HPGCL	Panipat Thermal Power Station	210
7	OPGLC	IB Valley Thermal Power Station	210
8	PSEB	Guru Hargobind Singh Thermal Power Station, Lehra Mohabbat	210
9	NLCL	Neyveli Lignite Corporation	210
10	NLCL	Neyveli Lignite Corporation	210
11	MPPGCL	Satpura Thermal Power Station	210
12	RRVUNL	Suratgarh Thermal Power Station	250
13	TNEB	Tuticorn Thermal Power Station	210
14	MAHAGENCO	Chandrapur Thermal Power Station	500
15	MAHAGENCO	Chandrapur Thermal Power Station	210
16	MAHAGENCO	Koradi Thermal Power Station	200
17	WBPDCL	Bandel Thermal Power Station	210
18	MAHAGENCO	Bhusawal Thermal Power Station	210
19	Chhattisgarh SEB	Korba Thermal Power Station	210
20	PSEB	Guru Gobind Singh Thermal Power Station, Ropar	210
21	GSECL	Ukai Thermal Power Station	210
22	TNEB	North Chennai Thermal Power Station	210
23	GSECL	Ukai Thermal Power Station	200
24	GSECL	Ukai Thermal Power Station	210
25	DVC	Bokaro Thermal Power Station	210
26	GSCEL	Wanakbori Thermal Power Station	210
27	GSCEL	Wanakbori Thermal Power Station	210
28	DVC	Durgapur Thermal Power Station	210
29	DVC	Mejia Thermal Power Station	210
30	APGENCO	Vijayawada Thermal Power Station	210
31	APGENCO	Kothagudem Thermal Power Station	250
32	Chhattisgarh SEB	Korba East Thermal Power Station	120
33	UPRVUNL	Anpara Thermal Power Station	210
34	UPRVUNL	Anpara Thermal Power Station	500
35	UPRVUNL	Obra Thermal Power Station	200

Report No	State Board/ Electricity Gen. Company	Power Station	Unit size
36	APGENCO	Vijayawada Thermal Power Station	210
37	APGENCO	Kothagudem Thermal Power Station	250
38	APGENCO	Rayalseema Thermal Power Station	210
39	WBPDCL	Bakreswar Thermal Power Station	210
40	MAHAGENCO	Parli Thermal Power Station	210
41	KPCL	Raichur Thermal Power Station	210
42	KPCL	Raichur Thermal Power Station	210
43	HPGCL	Panipat Thermal Power Station	110
44	APGENCO	Kothagudem Thermal Power Station	120
45	UPRVUNL	Obra Thermal Power Station	110
46	UPRVUNL	Pariccha Thermal Power Station	210
47	UPRVUNL	Pariccha Thermal Power Station	110
48	GSECL	Dhuvaran Thermal Power Station	140
49	GSECL	Gandhinagar Thermal Power Station	120
50	GSECL	Wanakbori Thermal Power Station	210
51	TVNL	Tenughat Thermal Power Station	210
52	GSECL	Ukai Thermal Power Station	120
53	HPGCL	Panipat Thermal Power Station	250
54	GIPCL	Surat Lignite	125
55	GSECL	Sikka Thermal Power Station	120
56	DVC	Chandarapura Thermal Power Station	140
57	MPPGCL	Birsinghpur (Sanjay Gandhi) Thermal Power Station T.P.S.	210
58	MPPGCL	Amarkantak Thermal Power Station	120
59	WBPDCL	Santaldih Thermal Power Station	120
60	DVC	Durgapur Thermal Power Station	140
61	APGENCO	Kothagudem Thermal Power Station	120
62	APGENCO	Rayalseema Thermal Power Station	210
63	OPGCL	IB Valley Thermal Power Station	210
64	UPRVUNL	Obra Thermal Power Station	200
65	UPRVUNL	Panki Thermal Power Station	105
66	RRVUNL	Kota Thermal Power Station	110
67	RRVUNL	Kota Thermal Power Station	210
68	UPRVUNL	Paricha Thermal Power Station	210
69	TNEB	North Chennai Thermal Power Station	210
70	TNEB	Mettur Thermal Power Station	210
71	TNEB	Ennore Thermal Power Station	110
72	MAHAGENCO	Chandrapur Thermal Power Station	500
73	MAHAGENCO	Koradi Thermal Power Station	210
74	PSEB	Guru Nanak Dev Thermal Power Station,	110

Report No	State Board/ Electricity Gen. Company	Power Station	Unit size
		Bathinda	
75	APGENCO	Vijayawada Thermal Power Station	210
76	Chhattisgarh SEB	Korba Thermal Power Station	210
77	PSEB	Guru Gobind Singh Thermal Power Station, Ropar	210
78	PSEB	Guru Gobind Singh Thermal Power Station. Ropar	210
79	MAHAGENCO	Khapar Kheda Thermal Power Station	210
80	MAHAGENCO	Nashik Thermal Power Station	140
81	MAHAGENCO	Nashik Thermal Power Station	210
82	RRUVNL	Kota Thermal Power Station	195
83	UPRVUNL	Anpara Thermal Power Station	500
84	RRVUNL	Suratgarh Thermal Power Station	250
85	MAHAGENCO	Chandrapur Thermal Power Station	500

Note: Observations/analysis presented in the table are based on the operating parameters as observed at the time of Mapping Studies

Operating indices for 500 MW units

ANNEXURE-2A

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
								Flow (t/h)	Tempera-ture (°C)	Pressure (kg/cm2)		
1	1991	17	Design	500	2238.0	1972.0	88.10	1,524.0	537.0	170.0	670.8	8.69
			Operating	481	2508.0	2093.0	83.50	1,455.0	538.0	165.0	650.0	
			Dev (%)	-3.8%	12.1%	6.1%	-5.2%	-4.5%	0.2%	-2.9%	-3.1%	
2	1992	16	Design	500	2238.0	1972.0	88.10	1,524.0	538.0	174.0	675.0	7.71
			Operating	370	2646.7	2090.9	79.00	1,137.0	539.0	143.0	651.0	
			Dev (%)	-26.0%	18.3%	6.0%	-10.3%	-25.4%	0.2%	-17.8%	-3.6%	
3	1997	11	Design	500	2238.0	1972.0	88.10	1,524.0	537.0	170.0	670.8	7.81
			Operating	457	2563.0	2087.0	81.40	1,207.0	537.0	170.0	636.1	
			Dev (%)	-8.6%	14.5%	5.8%	-7.6%	-20.8%	0.0%	0.0%	-5.2%	
4	1994	14	Design	500	2281.0	1984.3	87.00	1,507.8	538.0	169.0	760.0	7.51
			Operating	425	2590.0	2178.6	84.12	1,315.0	540.0	168.0	715.0	
			Dev (%)	-15.0%	13.5%	9.8%	-3.3%	-12.8%	0.4%	-0.6%	-5.9%	
5	1994	14	Design	500.21	2277.9	1981.8	87.00	1,509.0	538.0	173.3	690.0	7.50
			Operating	498.51	2523.4	2095.7	83.05	1,550.0	542.0	171.3	670.0	
			Dev (%)	-0.3%	10.8%	5.8%	-4.5%	2.7%	0.7%	-1.2%	-2.9%	
Total – **Average Design Values**				**500.0**	**2254.6**	**1976.4**	**87.66**	**1,517.8**	**537.6**	**171.3**	**693.3**	**7.84**
Average Operating Values				**446.3**	**2566.2**	**2109.1**	**82.21**	**1,332.8**	**539.2**	**163.5**	**664.4**	
Average Deviations (%)				**-10.7%**	**13.8%**	**6.7%**	**-6.2%**	**-12.2%**	**0.3%**	**-4.5%**	**-4.1%**	
Minimum of Operating Values				**370**	**2508.0**	**2087.0**	**79.00**	**1,137.0**	**537.0**	**143.0**	**636.1**	**7.50**
Maximum of Operating Values				**498.5**	**2646.7**	**2178.6**	**84.12**	**1,550.0**	**542.0**	**171.3**	**715.0**	**8.69**

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 250 MW units

ANNEXURE-2B

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam Flow (tph)	Main Steam Tempera-ture (°C)	Main Steam Pressure (kg/cm²)	Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
1	1997	11	Design	250	2304.6	2004.2	87.10	760.0	537.0	150.0	700.0	9.58
			Operating	250	2698.8	2231.9	82.70	750.0	544.0	154.0	680.0	
			Dev (%)	0.0%	16.9%	11.3%	-5.1%	-1.3%	1.3%	2.7%	-2.9%	
2	1998	10	Design	250	2305.0	2004.0	87.12	760.0	537.0	150.0	700.0	10.04
			Operating	250	2771.0	2294.0	82.70	785.0	530.0	144.0	680.0	
			Dev (%)	0.0%	19.8%	14.3%	-5.1%	3.3%	-1.3%	-4.0%	-2.9%	
3	2005	3	Design	250	2286.2	2005.0	87.70	740.0	537.0	152.0	680.0	8.54
			Operating	258	2667.0	2210.6	82.90	790.0	535.0	151.7	656.0	
			Dev (%)	3.2%	16.7%	10.3%	-5.5%	6.8%	-0.4%	-0.2%	-3.5%	
4	1998	10	Design	250	2303.1	2004	87.00	740.9	537.0	147.0	665.0	9.33
			Operating	242.63	2751.1	2284.0	83.00	790.0	538.0	152.0	639.0	
			Dev (%)	-2.9%	19.4%	13.9%	-4.6%	6.6%	0.2%	3.4%	-3.9%	
5	2000	8	Design	250	2304	2004	87.00	740.8	540.0	154.1	665.0	9.73
			Operating	256	2546.1	2179.2	85.60	788.0	538.0	152.4	654.0	
			Dev (%)	2.4%	10.5%	8.7%	-1.6%	6.4%	-0.4%	-1.1%	-1.7%	
Total	Average Design Values			**250.0**	**2300.7**	**2004.2**	**87.18**	**748.3**	**537.6**	**150.6**	**682.0**	**9.44**
	Average Operating Values			**251.3**	**2687.2**	**2239.9**	**83.38**	**780.6**	**537.0**	**150.8**	**661.8**	
	Average Deviations (%)			**0.5%**	**16.8%**	**11.7%**	**-4.4%**	**4.3%**	**-0.1%**	**0.2%**	**-3.0%**	
	Minimum of Operating Values			**242.63**	**2546.1**	**2179.2**	**82.70**	**750.0**	**530.0**	**144.0**	**639.0**	**8.54**
	Maximum of Operating Values			**258.0**	**2773.0**	**2294.0**	**85.60**	**790.0**	**544.0**	**154.0**	**680.0**	**10.04**

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 210 MW units

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
								Flow (t/h)	Tempera-ture (°C)	Pressure (kg/cm2)		
1	1994	14	Design	210	2270.8	2007.4	88.40	640.0	540.0	147.0	672.0	9.75
			Operating	210.38	2480.6	2110.0	85.00	668.0	538.0	150.0	660.0	
			Dev (%)	0.2%	9.2%	5.1%	-3.8%	4.4%	-0.4%	2.0%	-1.8%	
2	2007	1	Design	210.2	2270.8	2007.4	88.40	646.0	537.0	147.0	690.0	11.29
			Operating	179.44	2383.7	2050.0	86.00	556.0	537.0	147.0	684.0	
			Dev (%)	-14.6%	5,6%	2.1%	-2.7%	-13.9%	0.0%	0.0%	-0.9%	
3	1979	29	Design	210	2397.0	2062.0	86.00	673.0	540.0	130.0	710.0	8.92
			Operating	210.3	2642.9	2186.6	82.80	726.0	535.0	130.0	680.0	
			Dev (%)	0.1%	10.3%	6.0%	-3.7%	7.9%	-0.9%	0.0%	-4.2%	
4	1994	14	Design	210.4	2331.8	2007.8	86.10	630.0	539.0	150.0	710.0	8.51
			Operating	210	2490.1	2110.5	84.75	635.0	540.0	149.0	695.0	
			Dev (%)	-0.2%	6.8%	5.1%	-1.6%	0.8%	0.2%	-0.7%	-2.1%	
5	1995	13	Design	210	2332.0	2007.0	86.10	630.0	540.0	150.0	693.0	9.70
			Operating	214	2445.0	2093.5	85.60	666.0	540.0	149.5	695.0	
			Dev (%)	1.9%	4.8%	4.3%	-0.6%	5.7%	0.0%	-0.3%	0.3%	
6	1984	24	Design	210	2333.7	2007.0	86.00	625.0	535.0	147.0	684.0	9.87
			Operating	207	2602.1	2178.5	83.70	620.0	536.0	133.0	631.0	
			Dev (%)	-1.4%	11.5%	8.5%	-2.7%	-0.8%	0.2%	-9.5%	-7.7%	
7	1986	22	Design	210	2333.7	2007.0	86.10	630.0	540.0	150.0	680.0	10.05
			Operating	160.4	2859.6	2209.2	77.25	505.0	535.0	134.6	660.0	
			Dev (%)	-23.6%	22.5%	10.1%	-10.3%	-19.8%	-0.9%	-10.3%	-2.9%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 210 MW units

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
			Design	210.4	2403.5	2067.0	86.00	678.0	535.0	129.0	684.0	
8	1986	22	Operating	175.3	3063.6	2407.0	78.56	614.0	533.0	115.0	660.0	9.50
			Dev (%)	-16.7%	27.5%	16.4%	-8.7%	-9.4%	-0.4%	-10.9%	-3.5%	
			Design	210	2378.5	2072.0	87.13	645.0	540.0	137.0	680.0	
9	1982	26	Operating	192	2888.6	2296.4	79.50	600.0	527.0	133.0	627.0	11.19
			Dev (%)	-8.6%	21.4%	10.8%	-8.8%	-7.0%	-2.4%	-2.9%	-7.8%	
			Design	210.42	2306.0	2007.0	87.00	632.0	540.0	150.0	690.0	
10	1997	11	Operating	219	2703.0	2216.5	82.00	656.0	515.0	146.0	670.0	9.70
			Dev (%)	4.1%	17.2%	10.4%	-5.7%	3.8%	-4.6%	-2.7%	-2.9%	
			Design	210.36	2360.0	2002.0	84.85	630.0	540.0	150.0	690.0	
11	1990	18	Operating	170.28	2824.3	2234.8	79.10	535.0	535.0	149.0	660.0	11.82
			Dev (%)	-19.1%	19.7%	11.6%	-6.8%	-15.1%	-0.9%	-0.7%	-4.3%	
			Design	210	2376.0	2044.0	86.00	690.0	540.0	135.0	690.0	
12	1985	23	Operating	207.78	2746.2	2265.5	82.50	708.0	533.0	126.0	679.0	9.11
			Dev (%)	-1.1%	15.6%	10.8%	-4.1%	2.6%	-1.3%	-6.7%	-1.6%	
			Design	210	2403.2	2067.1	86.00	678.0	540.0	129.0	680.0	
13	1982	26	Operating	200	2740.0	2247.0	82.00	680.0	527.7	124.0	644.0	9.02
			Dev (%)	-4.8%	14.1%	8.7%	-4.7%	0.3%	-2.3%	-3.9%	-5.3%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
14	1984	24	Design	210	2403.2	2067	86.00	680.0	540.0	129.0	680.0	8.90
			Operating	190	2877.0	2359.0	82.00	651.0	535.0	123.0	635.0	
			Dev (%)	-9.5%	19.7%	14.1%	-4.7%	-4.3%	-0.9%	-4.7%	-6.6%	
15	1986	22	Design	210	2333.7	2007.0	86.10	635.0	535.0	147.0	680.0	9.32
			Operating	195.86	2839.1	2336.7	82.30	605.0	535.0	151.0	640.0	
			Dev (%)	-6.7%	21.7%	16.4%	-4.4%	-4.7%	0.0%	2.7%	-5.9%	
16	1989	19	Design	210	2318.5	1994.2	86.00	635.0	540.0	150.0	684.0	8.89
			Operating	210	2716.3	2142.0	79.00	670.0	538.0	140.0	655.0	
			Dev (%)	0.0%	17.2%	7.4%	-8.1%	5.5%	-0.4%	-6.7%	-4.2%	
17	1991	19	Design	210.5	2307.0	2007.0	87.00	635.0	540.0	147.0	684.0	8.10
			Operating	215.26	2545.4	2138.0	84.00	665.0	540.3	144.9	679.0	
			Dev (%)	2.3%	10.3%	6.5%	-3.4%	4.7%	0.1%	-1.4%	-0.7%	
18	1994	14	Design	210	2304.8	1995.0	86.60	631.0	540.0	146.0	710.0	8.29
			Operating	206	2556.5	2167.9	84.80	632.0	538.7	143.4	661.0	
			Dev (%)	-1.9%	10.9%	8.7%	-2.1%	0.2%	-0.2%	-1.8%	-6.9%	
19	1982	26	Design	210	2403.0	2067.0	86.00	646.0	535.0	123.0	684.0	9.12
			Operating	210.78	2805.0	2272.0	81.00	648.0	535.0	116.0	670.0	
			Dev (%)	0.4%	17.3%	9.9%	-5.8%	0.3%	0.0%	-5.7%	-2.0%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

Board / Place	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
20	1986	22	Design	210	2403	2067	86.00	652.0	535.0	127.0	684.0	9.03
			Operating	200.88	2843.7	2304.9	81.05	670.0	532.0	119.0	660.0	
			Dev (%)	-4.3%	18.3%	11.5%	-5.8%	2.8%	-0.6%	-6.3%	-3.5%	
21	1989	19	Design	210	2317.3	2007.0	86.61	630.0	540.0	150.0	684.0	9.70
			Operating	210	2664.0	2122.0	79.60	640.0	533.0	147.0	660.0	
			Dev (%)	0.0%	15.0%	5.7%	-8.1%	1.6%	-1.3%	-2.0%	-3.5%	
22	1990	18	Design	210	2317.0	2007.0	86.60	628.0	535.0	150.0	684.0	9.19
			Operating	194	2984.0	2441.7	81.80	611.0	533.0	146.0	647.0	
			Dev (%)	-7.6%	28.8%	21.7%	-5.5%	-2.7%	-0.4%	-2.7%	-5.4%	
23	1982	26	Design	210	2395.4	2060.0	86.00	650.0	535.0	130.0	680.0	9.43
			Operating	188.9	2614.5	2192.7	83.90	588.0	535.0	130.0	662.0	
			Dev (%)	-10.0%	9.1%	6.4%	-2.4%	-9.5%	0.0%	0.0%	-2.6%	
24	1979	29	Design	210.18	2371.0	2040	86.00	652.0	535.0	130.0	680.0	9.92
			Operating	200	2697.0	2222.7	82.30	627.0	535.0	127.5	666.0	
			Dev (%)	-4.8%	13.7%	9.0%	-4.3%	-3.8%	0.0%	-1.9%	-2.1%	
25	1981	27	Design	210	2378.7	2040.0	85.80	670.0	535.0	130.0	680.0	9.48
			Operating	190	2948.4	2324.2	78.80	578.0	534.0	130.0	648.0	
			Dev (%)	-9.5%	24.0%	13.9%	-8.2%	-13.7%	-0.2%	0.0%	-4.7%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
26	1980	28	Design	210	2373.0	2040.0	86.00	670.0	535.0	137.0	663.0	12.87
			Operating	182	2715.0	2227.0	82.00	600.0	533.0	130.0	600.0	
			Dev (%)	-13.3%	14.4%	9.2%	-4.7%	-10.4%	-0.4%	-5.1%	-9.5%	
27	1993	15	Design	210.56	2334.0	2007.0	86.00	635.0	535.0	150.0	690.0	10.74
			Operating	148	2690.0	2208.0	82.10	442.0	535.0	93.8	660.0	
			Dev (%)	-29.7%	15.3%	10.0%	-4.5%	-30.4%	0.0%	-37.5%	-4.3%	
28	1980	28	Design	210	2409.0	2047.6	85.00	670.0	540.0	130.0	684.0	9.00
			Operating	175	2875.1	2342.9	81.50	650.0	525.0	108.0	650.0	
			Dev (%)	-16.7%	19.4%	14.4%	-4.1%	-3.0%	-2.8%	-16.9%	-5.0%	
29	1986	22	Design	210	2617.3	2012.7	76.90	641.9	535.0	150.0	689.0	10.05
			Operating	210.12	2970.4	2109.8	71.00	630.0	541.0	149.0	674.0	
			Dev (%)	0.1%	13.5%	4.8%	-7.7%	-1.8%	1.1%	-0.7%	-2.2%	
30	1993	15	Design	210	2570.0	2008.8	78.17	657.0	535.0	150.0	684.0	10.44
			Operating	210.19	2899.9	2235.1	77.10	660.0	535.0	149.0	667.0	
			Dev (%)	0.1%	12.8%	11.3%	-1.4%	0.5%	0.0%	-0.7%	-2.5%	
31	1994	14	Design	210	2350.0	1991.0	84.71	645.0	535.0	150.0	680.0	10.40
			Operating	210.39	2679.5	2223.0	83.00	660.0	536.0	148.0	655.0	
			Dev (%)	0.2%	14.0%	11.7%	-2.0%	2.3%	0.2%	-1.3%	-3.7%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
32	1995	13	Design	210	2369.3	2007.0	84.70	636.0	535.0	150.0	680.0	10.38
			Operating	183	2668.7	2201.8	82.50	616.0	543.0	145.0	642.0	
			Dev (%)	-12.9%	12.6%	9.7%	-2.6%	-3.1%	1.5%	-3.3%	-5.6%	
33	1998	10	Design	210	2335.6	2007.0	85.93	635.0	535.0	150.0	685.0	9.00
			Operating	210	2477.0	2044.8	82.55	645.0	535.0	147.0	655.0	
			Dev (%)	0.0%	6.1%	1.9%	-3.9%	1.6%	0.0%	-2.0%	-4.4%	
34	1985	23	Design	210	2333.3	2007.2	86.10	625.0	535.0	147.0	684.0	9.27
			Operating	210	2559.0	2116.1	82.70	620.0	535.0	140.0	667.0	
			Dev (%)	0.0%	9.7%	5.4%	-3.9%	-0.8%	0.0%	-4.8%	-2.5%	
35	1988	20	Design	210	2333.3	2007.2	86.10	625.0	535.0	147.0	684.0	9.15
			Operating	210	2672.1	2224.7	83.30	670.0	535.0	139.0	671.0	
			Dev (%)	0.0%	14.5%	10.8%	-3.3%	7.2%	0.0%	-5.4%	-1.9%	
36	1993	15	Design	210	2333.7	2007.0	86.00	630.0	535.0	147.0	684.0	9.50
			Operating	210	2867.1	2285.0	79.69	650.0	533.0	135.0	660.0	
			Dev (%)	0.0%	22.9%	13.9%	-7.3%	3.2%	-0.4%	-8.2%	-3.5%	
37	1989	19	Design	210	2333.7	2007.0	86.00	631.0	535.0	147.1	670.0	9.17
			Operating	210	2711.4	2250.4	83.00	658.0	535.0	147.1	605.0	
			Dev (%)	0.0%	16.2%	12.1%	-3.5%	4.3%	0.0%	0.0%	-9.7%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
38	1987	21	Design	210	2400	2062	85.93	650.0	540.0	136.0	684.0	9.12
			Operating	210	2656.2	2147.9	80.86	680.0	540.0	130.0	650.0	
			Dev (%)	0.0%	10.7%	4.3%	-5.9%	4.6%	0.0%	-4.4%	-5.0%	
39	1990	18	Design	210	2395.9	2060.0	86.00	670.0	540.0	136.0	700.0	8.66
			Operating	204	2529.4	2152.0	85.10	633.0	540.0	132.9	663.0	
			Dev (%)	-2.9%	5.6%	4.5%	-1.0%	-5.5%	0.0%	-2.3%	-5.3%	
40	1994	14	Design	210.52	2312.5	2005.8	86.73	640.0	539.0	147.0	690.0	9.78
			Operating	210.36	2650.8	2232.8	84.23	628.0	535.0	149.2	680.0	
			Dev (%)	-0.1%	14.6%	11.3%	-2.9%	-1.9%	-0.7%	1.5%	-1.4%	
41	1995	13	Design	210	2312.4	2005.8	86.70	640.0	535.0	147.1	690.0	8.92
			Operating	211.8	2575.3	2086.0	81.00	627.0	540.0	152.2	690.0	
			Dev (%)	0.9%	11.4%	4.0%	-6.6%	-2.0%	0.9%	3.5%	0.0%	
42	1979	29	Design	210	2378.0	2062.0	86.70	653.0	535.0	130.0	684.0	8.07
			Operating	210.29	2826.3	2259.8	80.00	722.0	535.0	125.0	640.0	
			Dev (%)	0.1%	18.6%	8.4%	-7.7%	10.6%	0.0%	-3.8%	-6.4%	
43	1996	12	Design	210	2318.6	1994.0	86.00	635.0	535.0	150.0	690.0	9.57
			Operating	180	2751.0	2160.0	78.50	526.0	526.0	124.0	660.0	
			Dev (%)	-14.3%	18.6%	8.3%	-8.7%	-17.2%	-1.7%	-17.3%	-4.3%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-2C

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
44	1987	21	Design	210.42	2333.7	2007.0	86.00	632.0	540.0	150.0	690.0	9.20
			Operating	184.38	2706.4	2192.4	81.00	600.0	530.0	144.0	680.0	
			Dev (%)	-12.4%	16.0%	9.2%	-5.8%	-5.1%	-1.9%	-4.0%	-1.4%	
45	2006	2	Design	210.36	2333.7	2007.0	86.00	630.0	540.0	150.0	690.0	9.76
			Operating	185.34	2751.5	2261.5	82.18	527.0	535.0	122.0	655.0	
			Dev (%)	-11.9%	17.9%	12.7%	-4.4%	-16.3%	-0.9%	-18.7%	-5.1%	
46	2006	2	Design	210	2333.0	2007.0	86.00	630.0	540.0	150.0	690.0	9.27
			Operating	202	2459.7	2090.7	85.00	570.0	563.9	136.4	632.0	
			Dev (%)	-3.8%	5.4%	4.2%	-1.2%	-9.5%	4.4%	-9.0%	-8.4%	
47	2000	8	Design	210	2303.2	1981.2	86.00	640.0	537.0	150.0	720.0	8.78
			Operating	210	2656.0	2238.3	84.27	658.0	530.0	148.1	690.0	
			Dev (%)	0.0%	15.3%	13.0%	-2.0%	2.8%	-1.3%	-1.3%	-4.2%	
48	1982	26	Design	210	2397	2062.2	86.00	660.0	535.0	127.5	684.0	8.68
			Operating	200	2747.3	2211.7	80.50	644.0	535.0	101.0	660.0	
			Dev (%)	-4.8%	13.6%	10.0%	-6.4%	-2.4%	0.0%	-20.8%	-3.5%	

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 210 MW units

ANNEXURE-2C

SL. NO.		Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
49		1984	24	Design	210	2388.1	2064.8	86.46	657.5	535.0	130.0	683.3	11.15
				Operating	183	2952.4	2347.0	79.50	635.0	530.0	107.0	670.0	
				Dev (%)	-12.9%	23.6%	13.7%	-8.0%	-3.4%	-0.9%	-17.7%	-1.9%	
Total	Average Design Values				210.1	2361.6	2025.5	85.8	645.1	537.3	142.2	686.5	9.57
	Average Operating Values				198.5	2714.4	2213.8	81.7	626.6	535.0	134.8	659.3	
	Average Deviations (%)				-5.5	14.9	9.3	-4.8	-2.9	-0.4	-5.2	-4.0	
	Minimum of Operating Values				148.0	2383.7	2044.8	71.0	442.0	515.0	93.8	600.0	8.07
	Maximum of Operating Values				219.0	3063.6	2441.7	86.0	726.0	563.9	152.2	695.0	12.87

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 195-200 MW units

ANNEXURE-2D

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
								Flow (tph)	Tempera-ture (°C)	Pressure (kg/cm2)		
1	2003	5	Design	195	2326	2000.0	86.00	583.5	540.0	147.1	680.0	10.00
			Operating	211	2392.6	2033.7	85.00	642.5	544.0	150.2	666.0	
			Dev (%)	8.2%	2.86%	1.6%	-1.2%	10.1%	0.7%	2.1%	-2.1%	
2	1979	29	Design	200	2403.0	2067.0	86.01	638.0	535.0	133.0	690.0	8.80
			Operating	194	2799.7	2267.2	80.98	614.0	535.0	106.0	687.0	
			Dev (%)	-3.0%	16.5%	9.7%	-5.8%	-3.8%	0.0%	-20.3%	-0.4%	
3	1978	30	Design	200.09	2403	2067.0	86.00	630.0	535.0	127.0	680.0	8.07
			Operating	180.86	2891.3	2340.8	81.00	633.0	518.0	123.5	659.0	
			Dev (%)	-9.6%	20.3%	13.20%	-5.8%	0.5%	-3.2%	-2.8%	-3.1%	
4	1979	29	Design	200	2395.0	2062.0	86.10	680.0	540.0	135.3	710.0	12.59
			Operating	100	3962.5	2892.5	73.00	360.0	535.0	62.7	660.0	
			Dev (%)	-50.0%	64.1%	39.3%	-15.2%	-47.1%	-0.9%	-53.7%	-7.0%	
5	1982	26	Design	200.09	2400.0	2062	86.00	680.0	540.0	136.0	690.0	11.74
			Operating	145.22	2899.5	2305.1	79.50	460.0	532.0	104.0	670.0	
			Dev (%)	-27.4%	20.7%	11.7%	-7.6%	-32.4%	-1.5%	-23.5%	-2.9%	
Total	Average Design Values			199.0	2399.6	2051.6	86.02	642.3	538.0	135.7	690.0	10.24
	Average Operating Values			166.2	2989.1	2367.9	79.90	541.9	532.8	109.3	668.4	
	Average Deviations (%)			-16.4%	24.4%	15.4%	-7.1%	-14.5%	-1.0%	-19.6%	-3.1%	
	Minimum of Operating Values			100	2392.6	2033.7	73.00	360.0	518.0	62.7	659.0	8.07
	Maximum of Operating Values			211.0	3962.5	2892.5	85.00	642.5	544.0	150.2	687.0	12.59

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating indices for 140 MW units

ANNEXURE-2E

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
								Flow (tph)	Tempera-ture (°C)	Pressure (kg/cm²)		
1	1968	40	Design	140	2462.9	2054.0	83.40	412.0	538.0	130.0	690.0	13.70
			Operating	112	2750.0	2242.9	81.50	344.0	530.0	124.5	660.0	
			Dev (%)	-20.0%	11.7%	9.2%	-2.3%	-16.5%	-1.5%	-4.2%	-4.3%	
2	1981	27	Design	140	2341.9	2054.0	86.23	395.0	540.0	130.0	690.0	14.13
			Operating	104.23	2904.8	2325.4	80.00	321.0	530.0	106.0	670.0	
			Dev (%)	-25.6%	24.0%	13.2%	-7.2%	-18.7%	-1.9%	-18.5%	-2.9%	
3	1972	36	Design	140.23	2361.0	2054.0	87.00	400.0	535.0	130.0	690.0	14.56
			Operating	104	2827.6	2298.0	81.30	315.0	520.0	120.0	670.0	
			Dev (%)	-25.8%	19.7%	7.7%	-6.6%	-21.3%	-2.8%	-7.7%	-2.9%	
4	1970	38	Design	140	2361	2054.0	87.0	428.4	543.0	141.0	663.0	8.91
			Operating	97	2814.0	2252.0	80.00	315.0	515.0	121.5	657.0	
			Dev (%)	-30.7%	19.1%	9.6%	-8.5%	-26.5%	-5.2%	-13.9%	-0.9%	
Total	Average Design Values			**140.1**	**2381.2**	**2054.0**	**86.01**	**408.9**	**539.0**	**132.8**	**683.3**	**12.83**
	Average Operating Values			**104.3**	**2824.1**	**2279.6**	**80.70**	**323.8**	**523.8**	**118.0**	**664.3**	
	Average Deviations (%)			**-25.5%**	**18.6%**	**11.0%**	**-6.1%**	**-20.7%**	**-2.8%**	**-11.1%**	**-2.8%**	
	Minimum of Operating Values			**97.0**	**2750.0**	**2242.9**	**80.00**	**315.0**	**515.0**	**106.0**	**657.0**	**8.91**
	Maximum of Operating Values			**112.0**	**2904.8**	**2325.4**	**81.50**	**344.0**	**530.0**	**124.5**	**670.0**	**14.6**

Note: Observations/analysis presented in the table are based on the operating parameters as observed at the time of Mapping Studies

Operating indices for 120-125 MW units

ANNEXURE-2F

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam Flow (tph)	Main Steam Tempera-ture (°C)	Main Steam Pressure (kg/cm^2)	Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
1	1974/2000	34	Design	120	2388.4	2054.7	86.00	360.0	540.0	130.4	690.0	10.02
			Operating	66	2764.1	2244.3	81.20	200.0	532.0	73.5	684.1	
			Dev (%)	-45.0%	15.7%	9.2%	-5.6%	-44.4%	-1.5%	-43.6%	-0.9%	
2	1978/2000	30	Design	120	2394.5	2054.7	86.00	362.0	535.0	130.0	690.0	13.47
			Operating	98	2709.7	2207.9	81.50	290.0	530.0	107.0	676.0	
			Dev (%)	-18.3%	13.2%	7.2%	-5.2%	-19.9%	-0.9%	-17.7%	-2.0%	
3	1981	27	Design	120	2442.0	2100	85.99	410.0	537.0	128.8	700.0	10.36
			Operating	114	2796.0	2261.5	80.88	410.0	532.0	126.2	680.0	
			Dev (%)	-5.0%	14.4%	7.7%	-5.9%	0.0%	-0.9%	-2.0%	-2.9%	
4	1977	31	Design	120	2442	2100	86.00	362.0	535.0	130.0	690.0	14.32
			Operating	102.9	2689.9	2187.7	81.30	320.0	530.0	120.0	670.0	
			Dev (%)	-14.3%	10.1%	4.1%	-5.5%	-11.6%	-0.9%	-7.7%	-2.9%	
5	1988	20	Design	120	2442.0	2100	85.50	372.0	537.0	127.0	684.0	13.66
			Operating	73	2801.7	2306.9	82.30	246.0	536.0	118.0	664.0	
			Dev (%)	-39.2%	14.8%	9.8%	-3.7%	-33.9%	-0.2%	-7.1%	-2.9%	
6	1976	32	Design	120	2346	2100	89.60	370.0	537.8	127.6	686.0	10.54
			Operating	108	2862.0	2360.6	82.50	328.0	510.0	106.0	663.0	
			Dev (%)	-10.0%	24.4%	14.5%	-7.9%	-11.4%	-5.2%	-16.9%	-3.4%	
7	1977	31	Design	120	2442	2100.0	86.00	403.0	540.0	133.0	686.0	12.41
			Operating	78.46	3730.0	2796.0	75.00	273.0	523.0	102.8	654.0	
			Dev (%)	-34.6%	54.2%	33.4%	-12.8%	-32.3%	-3.1%	-22.7%	-4.7%	

8	1974	34	Design	120.3	2442	2100.0	86.00	344.0	535.0	130.0	690.0	13.57
			Operating	70.3	3172.4	2478.5	78.10	248.0	505.0	78.8	660.0	
			Dev (%)	-41.6%	31.2%	18.2%	-9.2%	-27.9%	-5.6%	-39.4%	-4.3%	
9	1999	9	Design	125	2400.0	2022.0	84.30	390.0	540.0	132.0	710.0	11.50
			Operating	128	2771.0	2162.0	78.00	391.0	539.0	145.0	676.4	
			Dev (%)	2.4%	-15.5%	-6.9%	7.5%	-0.3%	0.2%	-9.8%	4.7%	
Total	Average Design Values			**120.6**	**2395.4**	**2063.4**	**86.15**	**374.8**	**537.4**	**129.9**	**691.8**	**12.21**
	Average Operating Values			**93.2**	**2921.9**	**2333.9**	**80.09**	**300.7**	**526.3**	**108.6**	**669.7**	
	Average Deviations (%)			**-22.8%**	**18.5%**	**11.5%**	**-5.4%**	**-20.2%**	**-2.0%**	**-18.6%**	**-2.1%**	
	Minimum of Operating Values			**66**	**2689.9**	**2162.0**	**75.00**	**200.0**	**505.0**	**73.5**	**654.0**	**10.02**
	Maximum of Operating Values			**128.0**	**3730.0**	**2796.0**	**82.50**	**410.0**	**539.0**	**145.0**	**684.1**	**14.32**

Note: Observations/analysis presented in the table are based on the operating parameters as observed at the time of Mapping Studies

ANNEXURE-2G

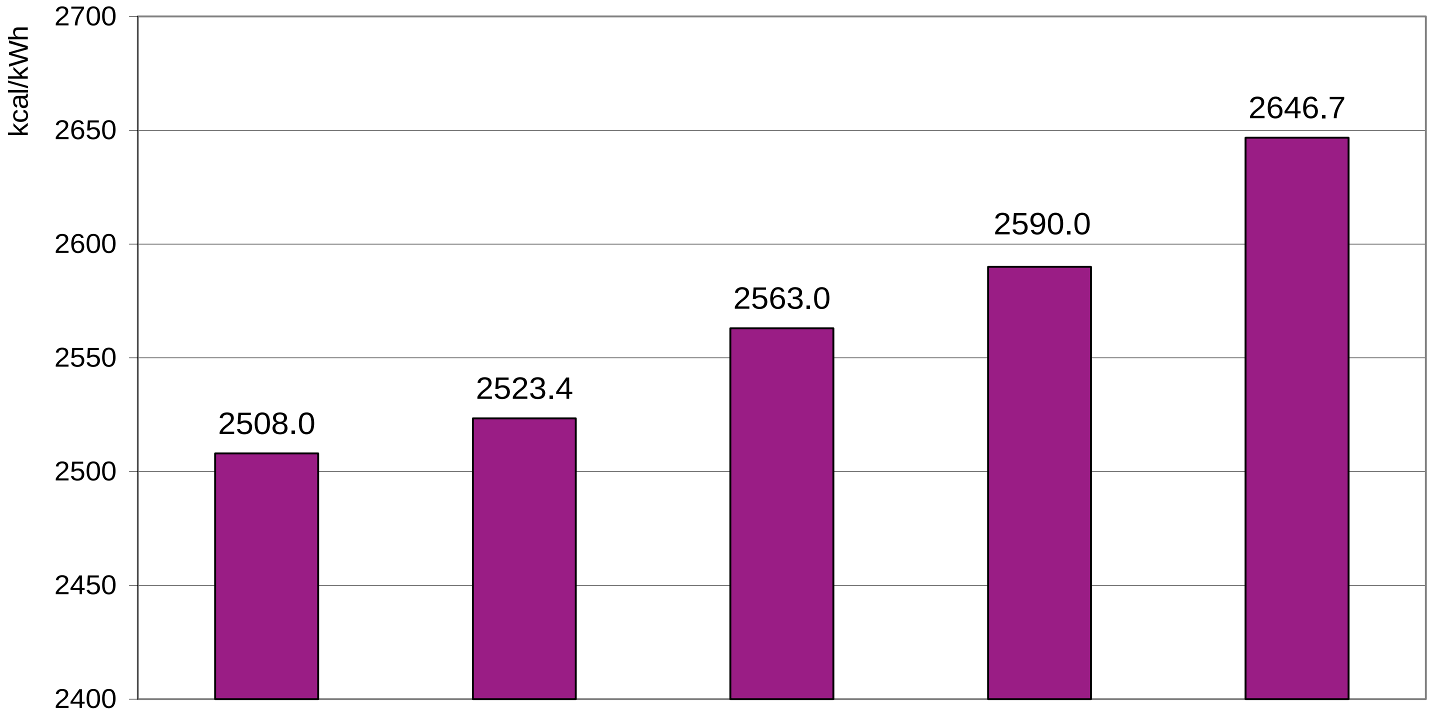
Operating indices for 100-110 MW units

SL. NO.	Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam			Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
								Flow (tph)	Tempera-ture (°C)	Pressure (kg/cm2)		
1	1975	33	Design	100	2472.0	2138.0	86.50	420.0	535.0	90.0	700.0	19.76
			Operating	52	2924.4	2310.3	79.00	220.0	525.0	68.9	682.0	
			Dev (%)	48.0%	-20.7%	-10.3%	8.7%	47.6%	1.9%	23.4%	2.6%	
2	1977	31	Design	105	2463.1	2140	86.90	320.0	535.0	130.4	684.0	14.14
			Operating	80	3280.7	2138	78.80	258.0	539.0	122.6	660.0	
			Dev (%)	23.8%	32.5%	-11.1%	9.3%	19.4%	-0.7%	6.0%	3.5%	
3	1985	23	Design	110	2377.0	2138.0	87.50	326.0	535.0	130.0	684.0	15.31
			Operating	103.43	2851.3	2310.3	81.00	330.0	515.0	118.0	638.0	
			Dev (%)	6.0%	20.0%	11.1%	-7.4%	1.2%	-3.7%	-9.2%	-6.7%	
4	1975	33	Design	110	2482.0	2120.0	89.48	324.0	540.0	129.0	681.2	9.60
			Operating	110.19	3067.5	2440.0	80.00	315.0	535.0	124.5	660.0	
			Dev (%)	-0.2%	-23.6%	-9.9%	10.6%	2.8%	0.9%	3.5%	3.1%	
5	1974	34	Design	110	2460.0	2120.0	86.00	324.0	540.0	139.0	680.0	9.11
			Operating	107	2696.3	2215.0	82.20	315.0	533.0	130.0	660.0	
			Dev (%)	2.7%	-9.6%	-4.7%	4.4%	2.8%	1.3%	6.5%	2.9%	
6	1983	25	Design	110	2245.6	2140.0	86.40	365.0	540.0	137.5	684.0	9.38
			Operating	109	2883.0	2372.7	82.30	366.0	534.0	127.3	645.0	
			Dev (%)	0.9%	-28.4%	-22.3%	4.7%	-0.3%	1.1%	7.4%	5.7%	
7	1975	33	Design	110	2395.9	2140.0	86.70	354.0	535.0	128.0	684.0	13.04
			Operating	75	3600.8	2881.4	80.00	285.0	537.5	121.0	560.0	
			Dev (%)	31.8%	-50.3%	-28.1%	7.7%	19.5%	-0.5%	5.5%	18.1%	
8	1984	24	Design	110	2418.6	2140.0	86.00	325.0	540.0	130.0	684.0	14.44
			Operating	85	2830.5	2230.6	78.80	257.0	538.0	96.0	638.0	

SL. NO.		Year of Commiss-ioning	Age till 2008	Mode	Load (MW)	Gross Heat Rate (kcal/kWh)	Turbine Heat Rate (kcal/kWh)	Boiler Efficiency (%)	Main Steam Flow (tph)	Main Steam Tempera-ture (°C)	Main Steam Pressure (kg/cm²)	Condenser Vacuum (mmHg)	Auxiliary Power Cons. (%)
				Dev (%)	22.7%	-17.0%	-7.2%	8.4%	20.9%	0.4%	26.2%	6.7%	
Total	Average Design Values				108.1	2434.9	2138.7	86.94	344.8	537.5	126.7	685.2	13.10
	Average Operating Values				90.2	3016.8	2418.3	80.26	293.3	532.1	113.5	642.9	
	Average Deviations (%)				17.0%	-19.0%	-10.3%	5.8%	14.2%	0.1%	8.6%	4.5%	
	Minimum of Operating Values				52	2696.3	2215.0	78.80	220.0	515.0	68.9	560.0	9.11
	Maximum of Operating Values				110.2	3600.8	2881.4	82.30	366.0	539.0	130.0	682.0	19.76

Note: Observations/analysis presented in the table are based on the operating parameters as observed at the time of Mapping Studies

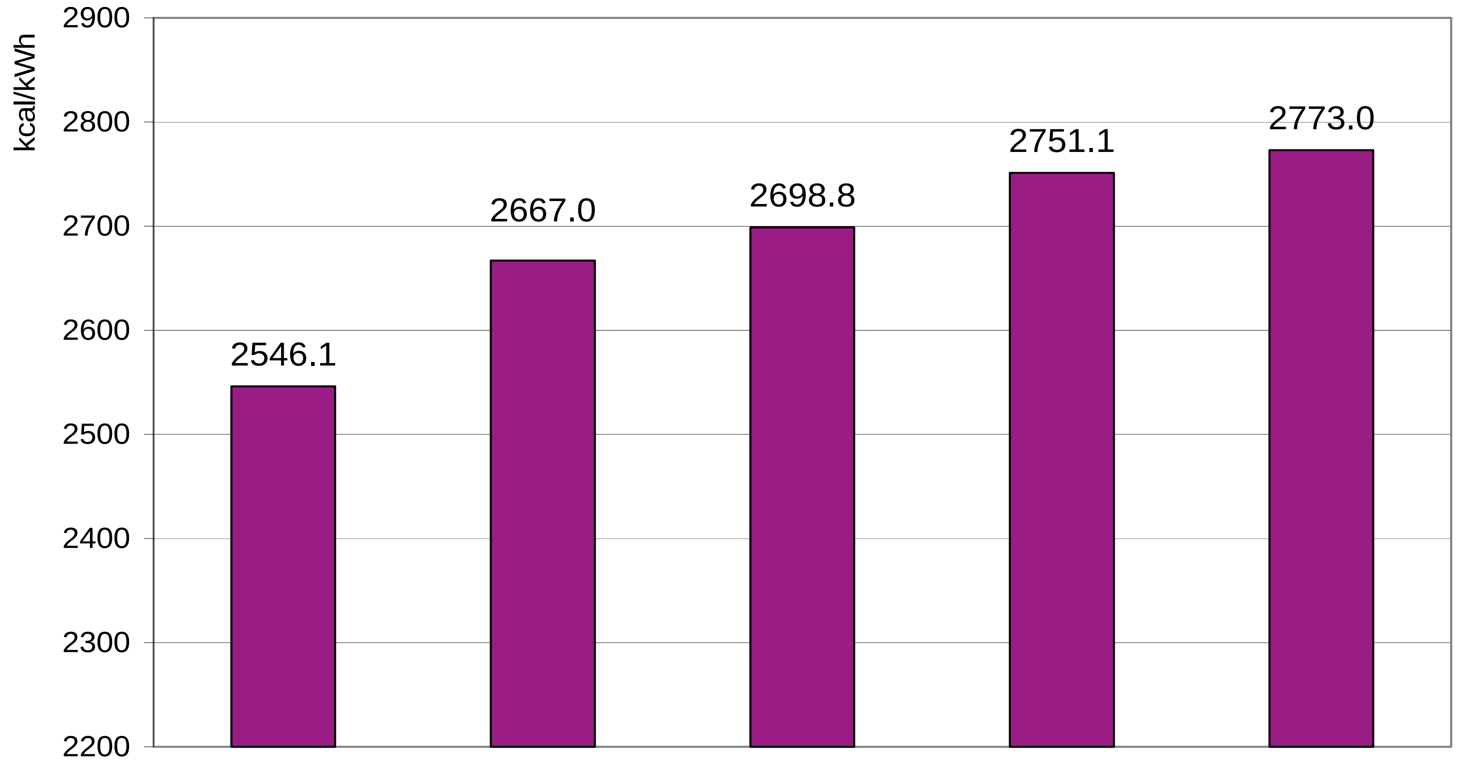
Operating Gross Heat Rate of 500 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the operating parameters as observed at the time of Mapping Studies

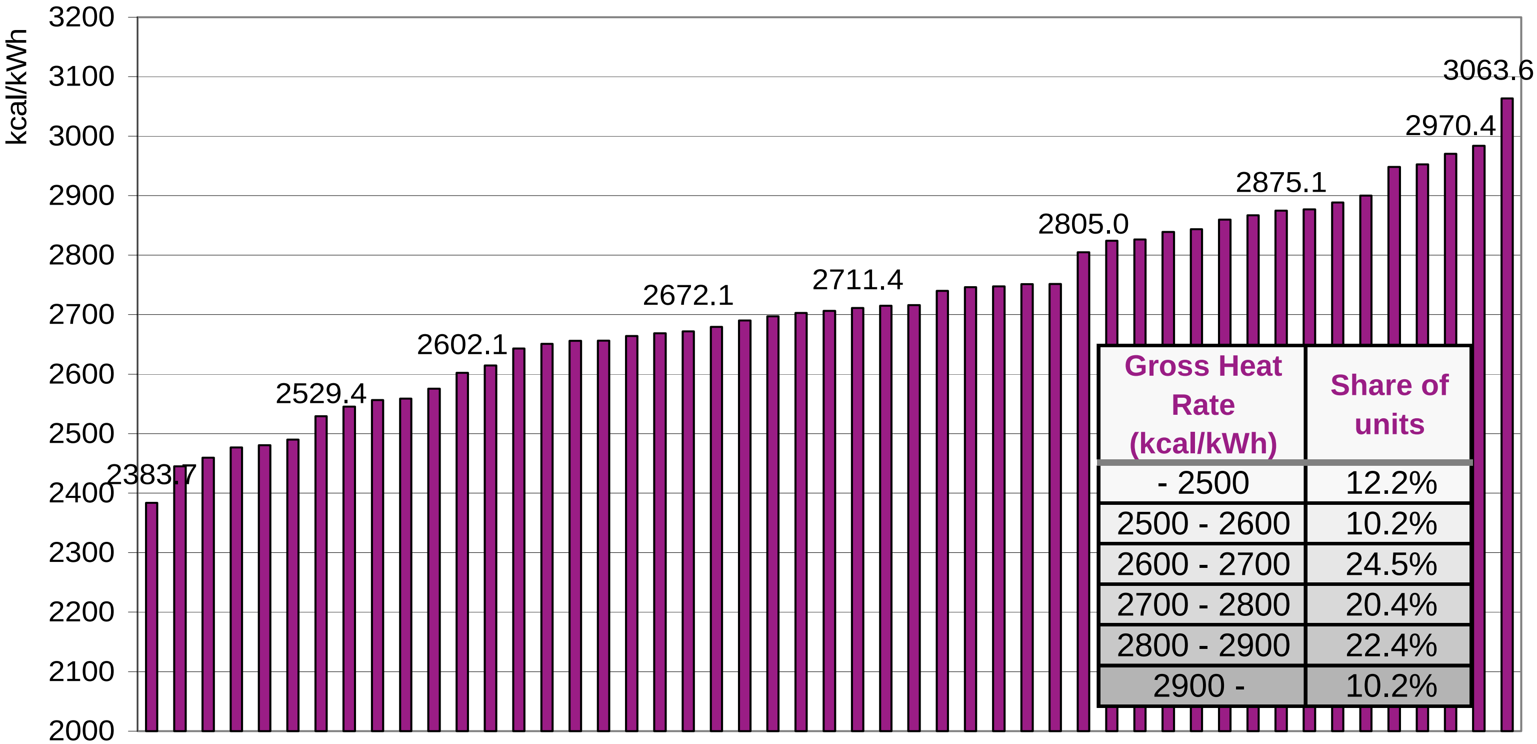
ANNEXURE-3B

Operating Gross Heat Rate of 250 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

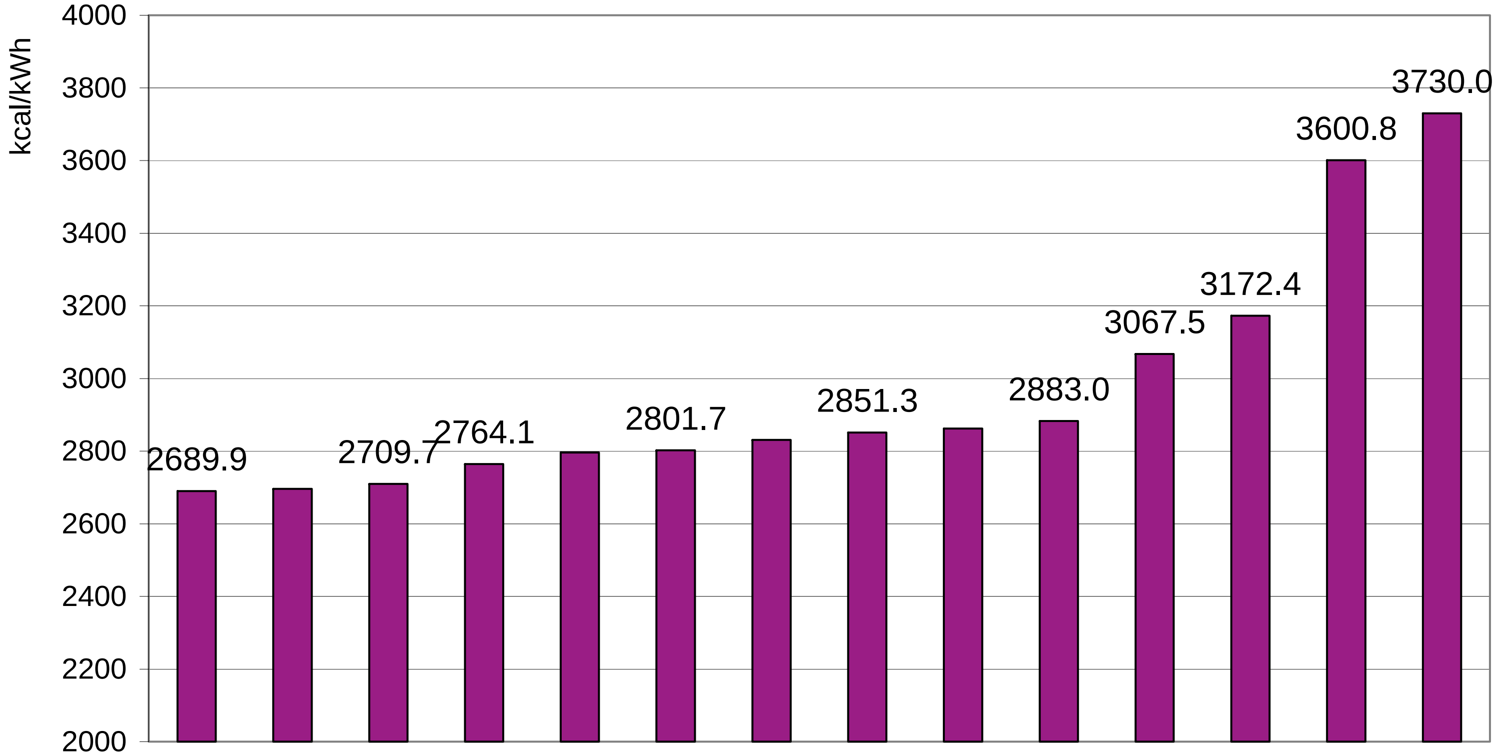
Operating Gross Heat Rate of 210 MW capacity units (kcal/kWh)



Gross Heat Rate (kcal/kWh)	Share of units
- 2500	12.2%
2500 - 2600	10.2%
2600 - 2700	24.5%
2700 - 2800	20.4%
2800 - 2900	22.4%
2900 -	10.2%

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

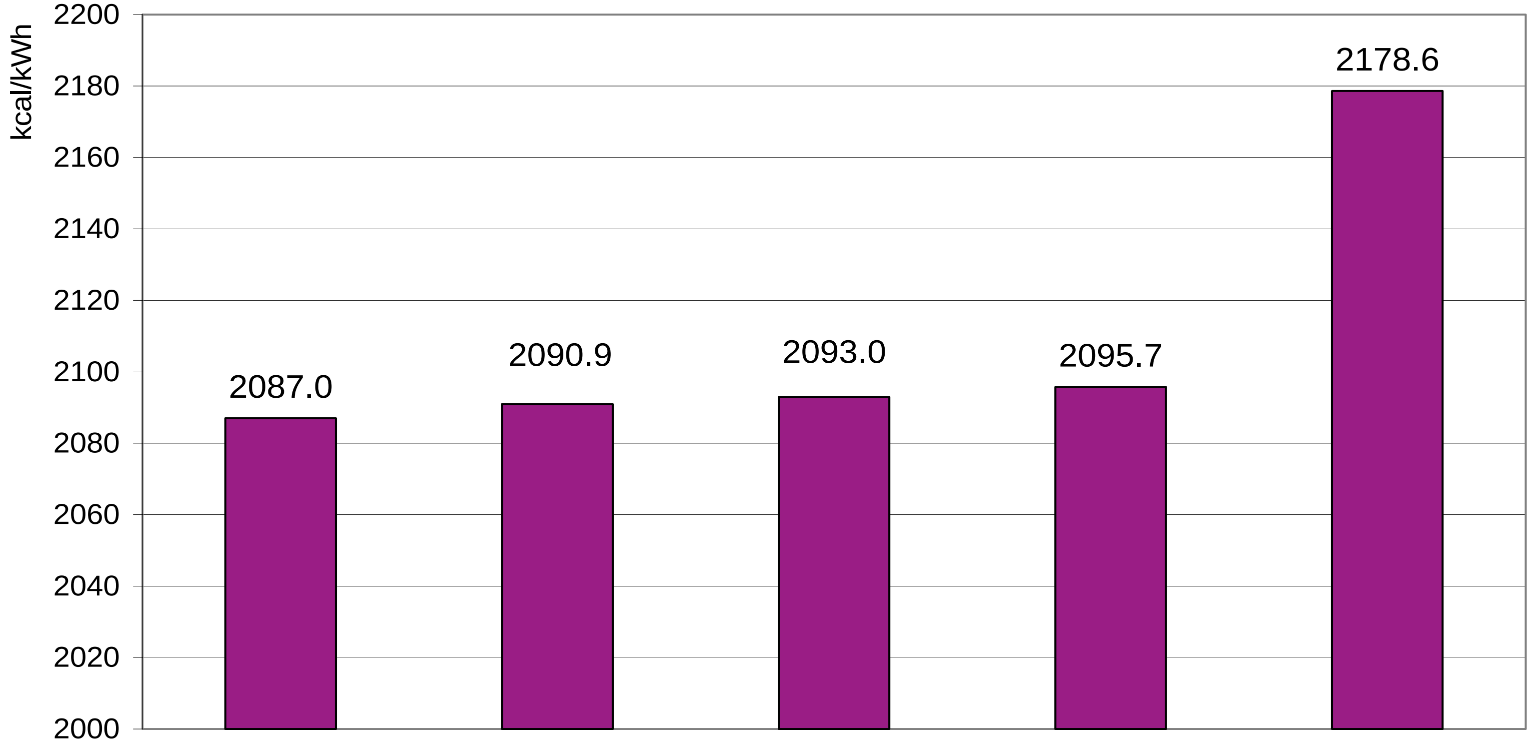
Operating Gross Heat Rate of 110-120 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-3E

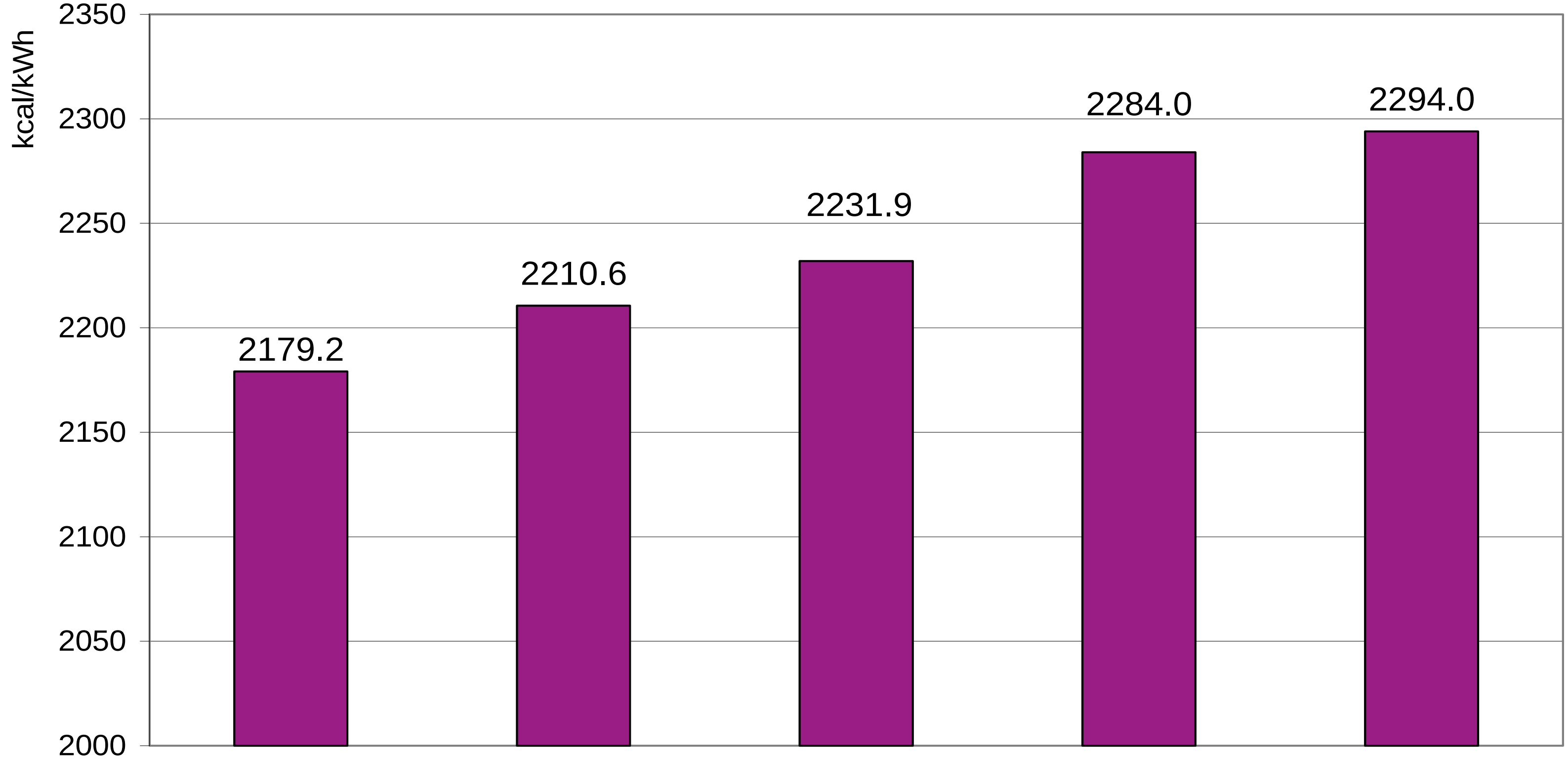
Operating Turbine Heat Rate of 500 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

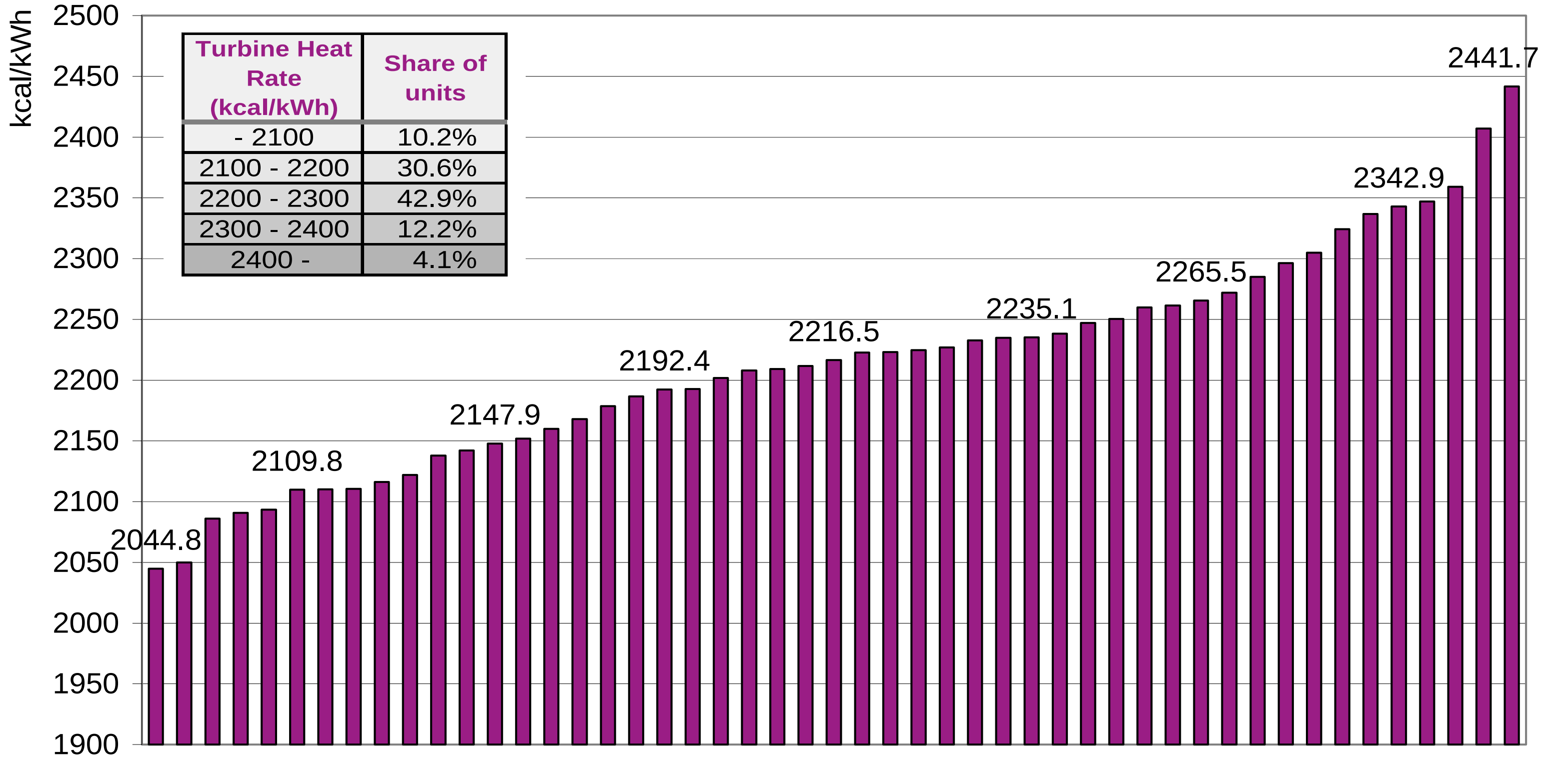
ANNEXURE-3F

Operating Turbine Heat Rate of 250 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

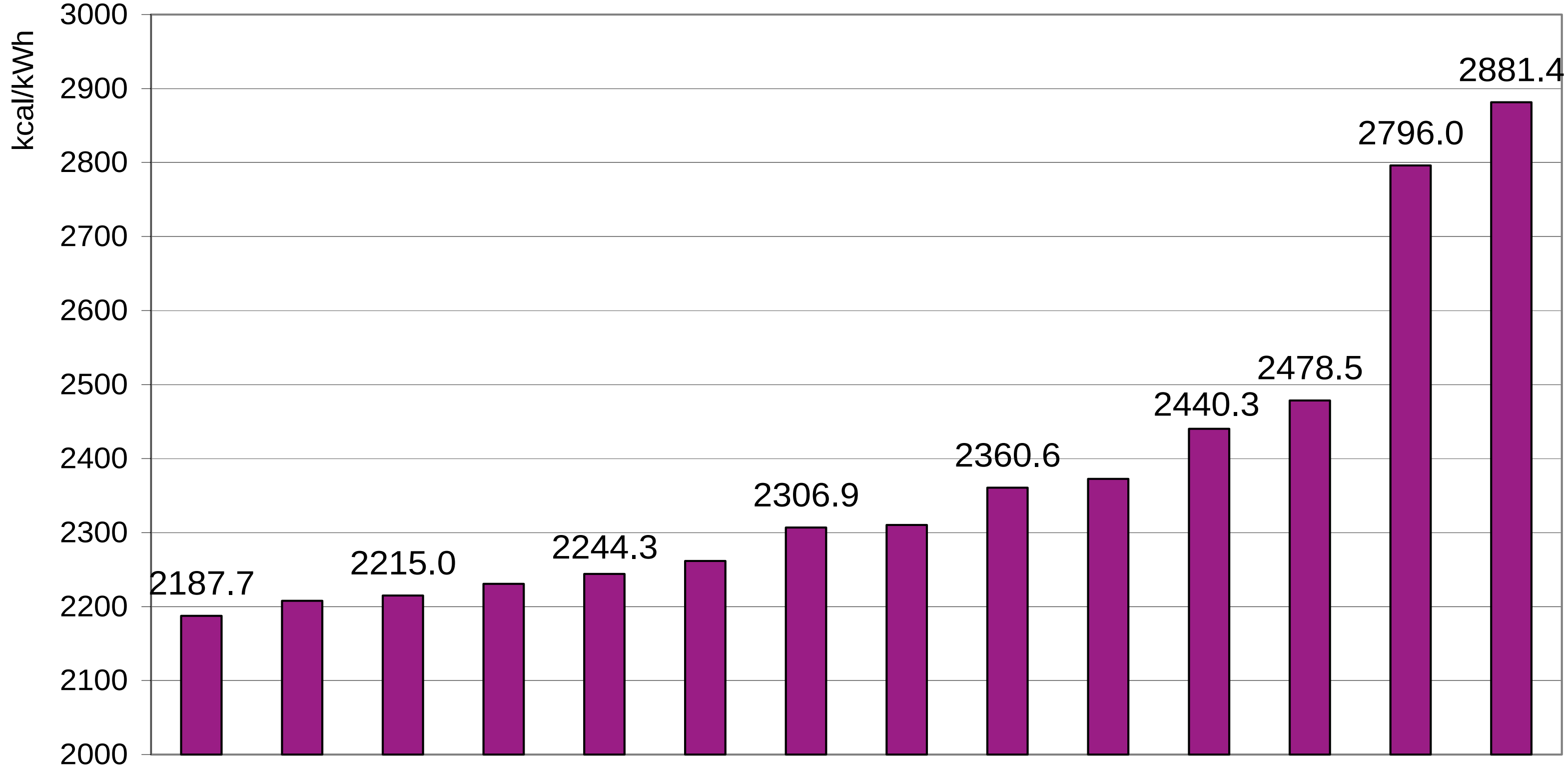
Operating Turbine Heat Rate of 210 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

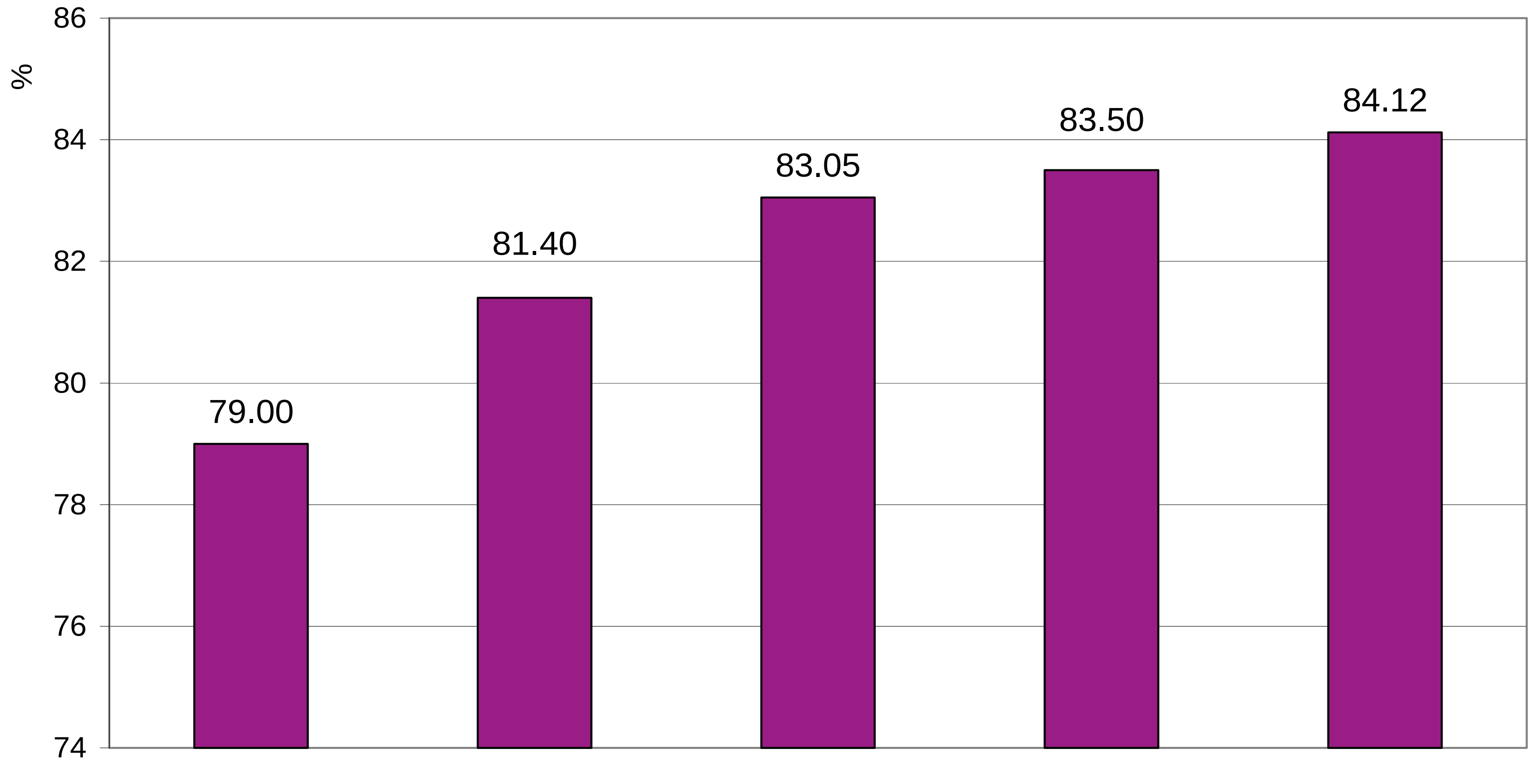
ANNEXURE-3H

Operating Turbine Heat Rate of 110-120 MW capacity units (kcal/kWh)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

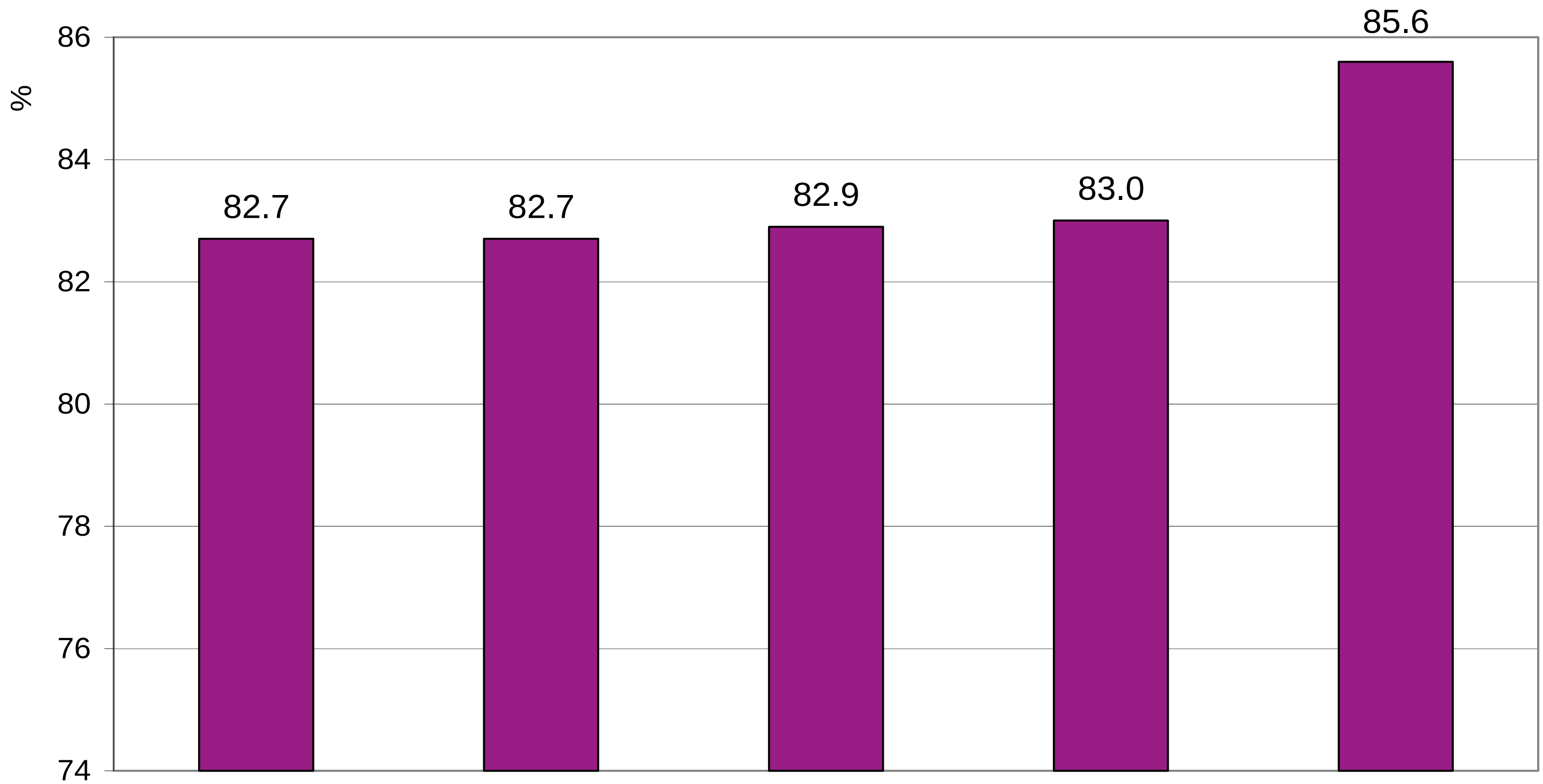
Operating Boiler Efficiency of 500 MW capacity units (%)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

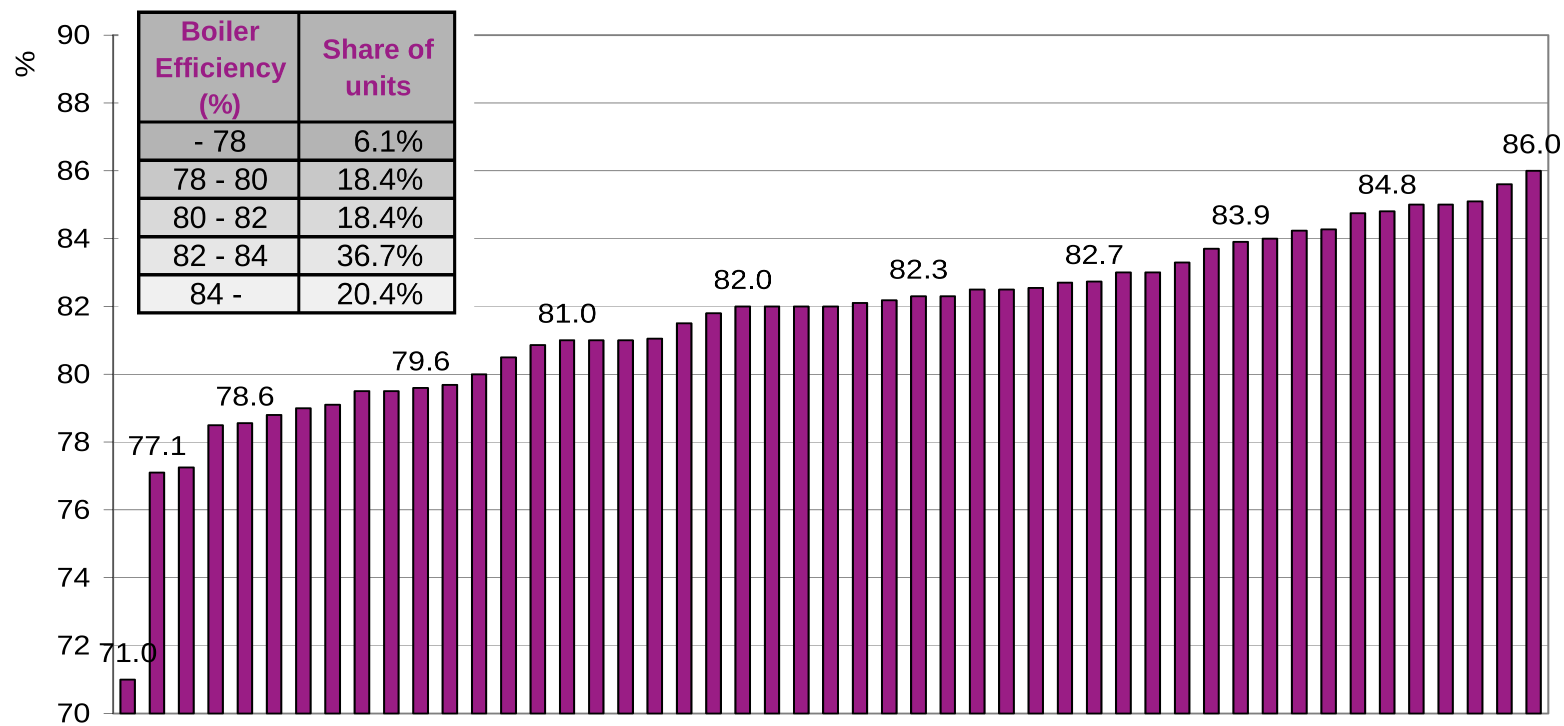
ANNEXURE-3J

Operating Boiler Efficiency of 250 MW capacity units (%)



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating Boiler Efficiency of 210 MW capacity units (%)

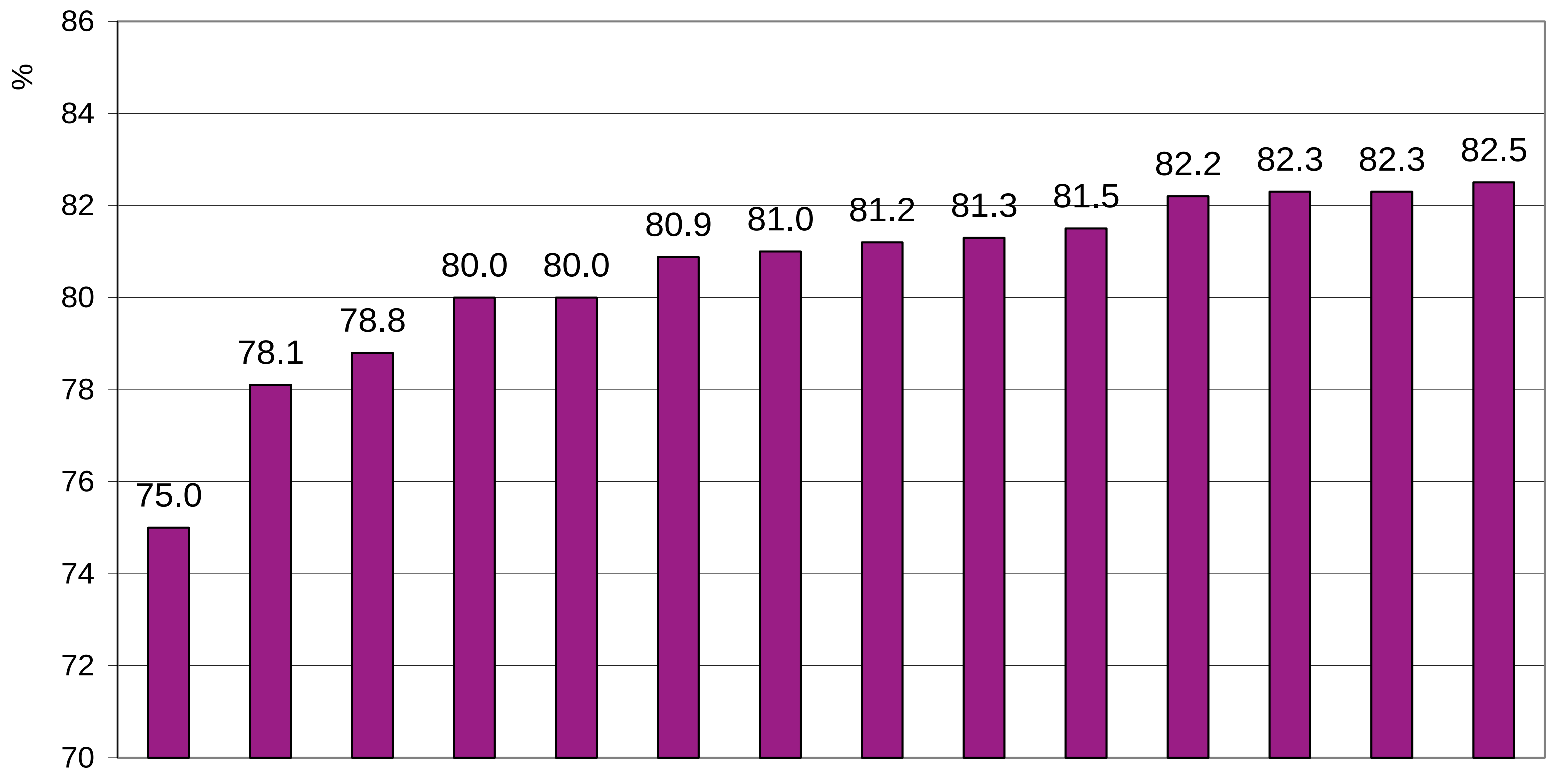


Boiler Efficiency (%)	Share of units
- 78	6.1%
78 - 80	18.4%
80 - 82	18.4%
82 - 84	36.7%
84 -	20.4%

Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

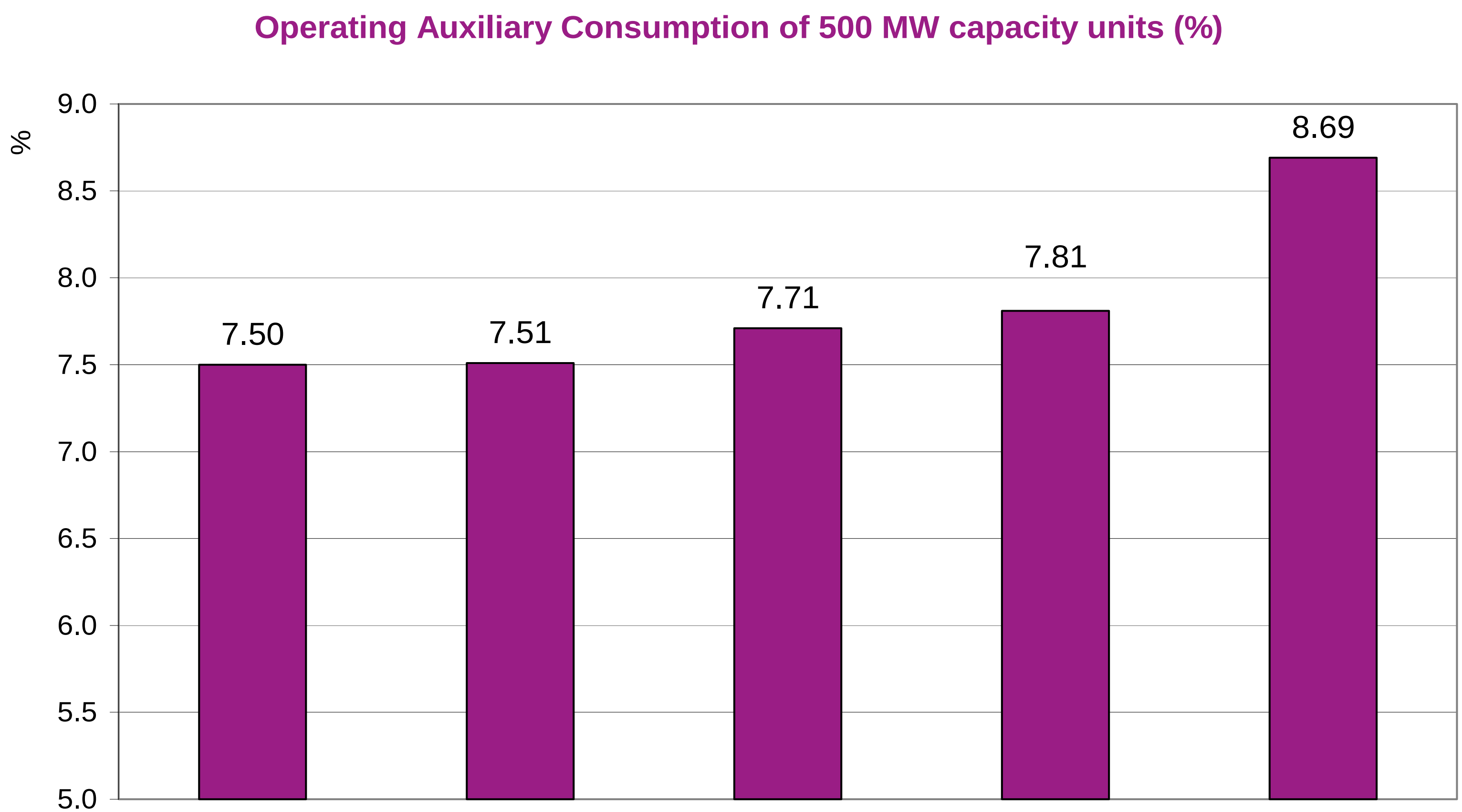
ANNEXURE-3L

Operating Boiler Efficiency of 110-120 MW capacity units (%)



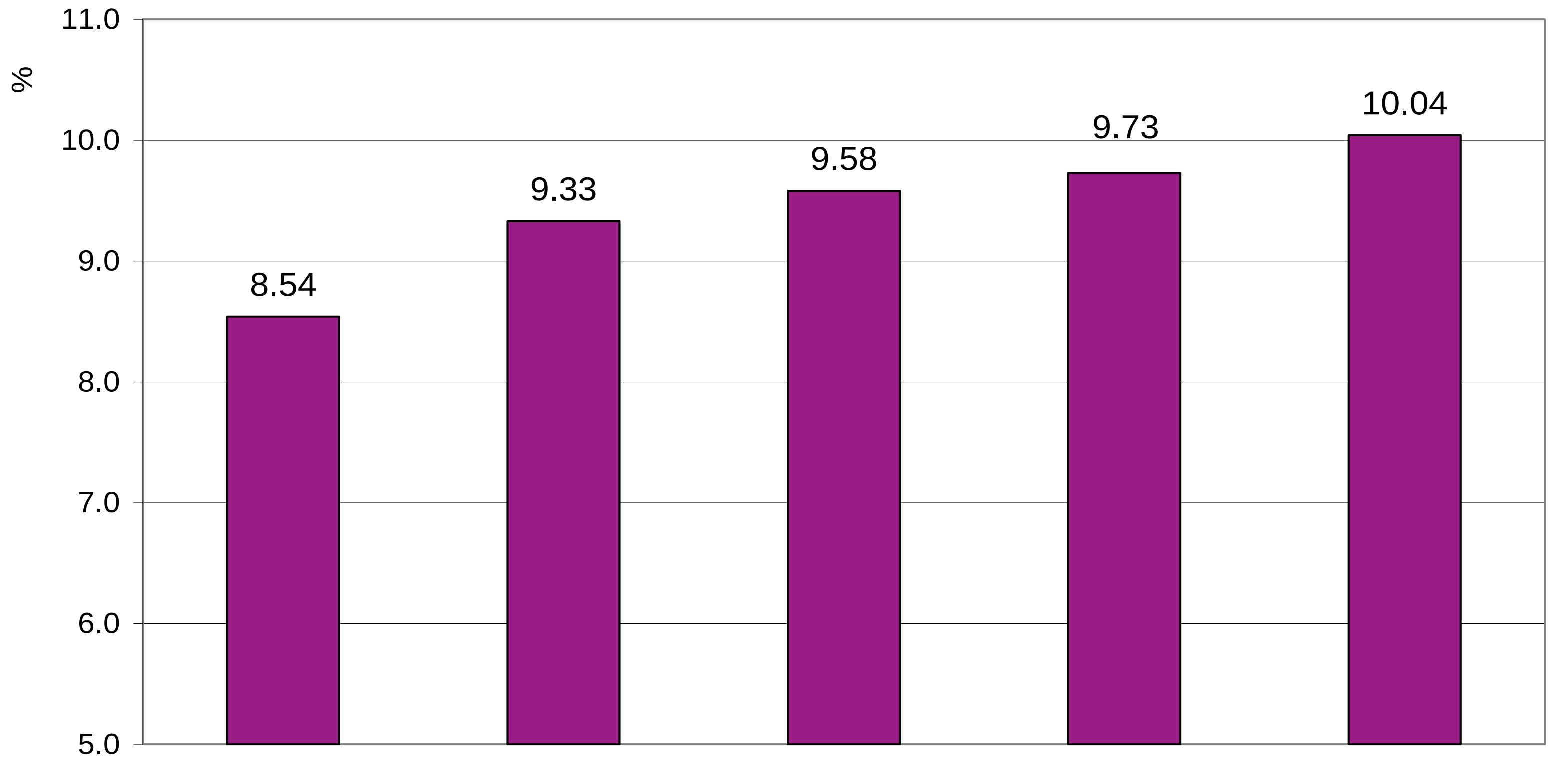
Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-3M



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Operating Auxiliary Consumption of 250 MW capacity units (%)

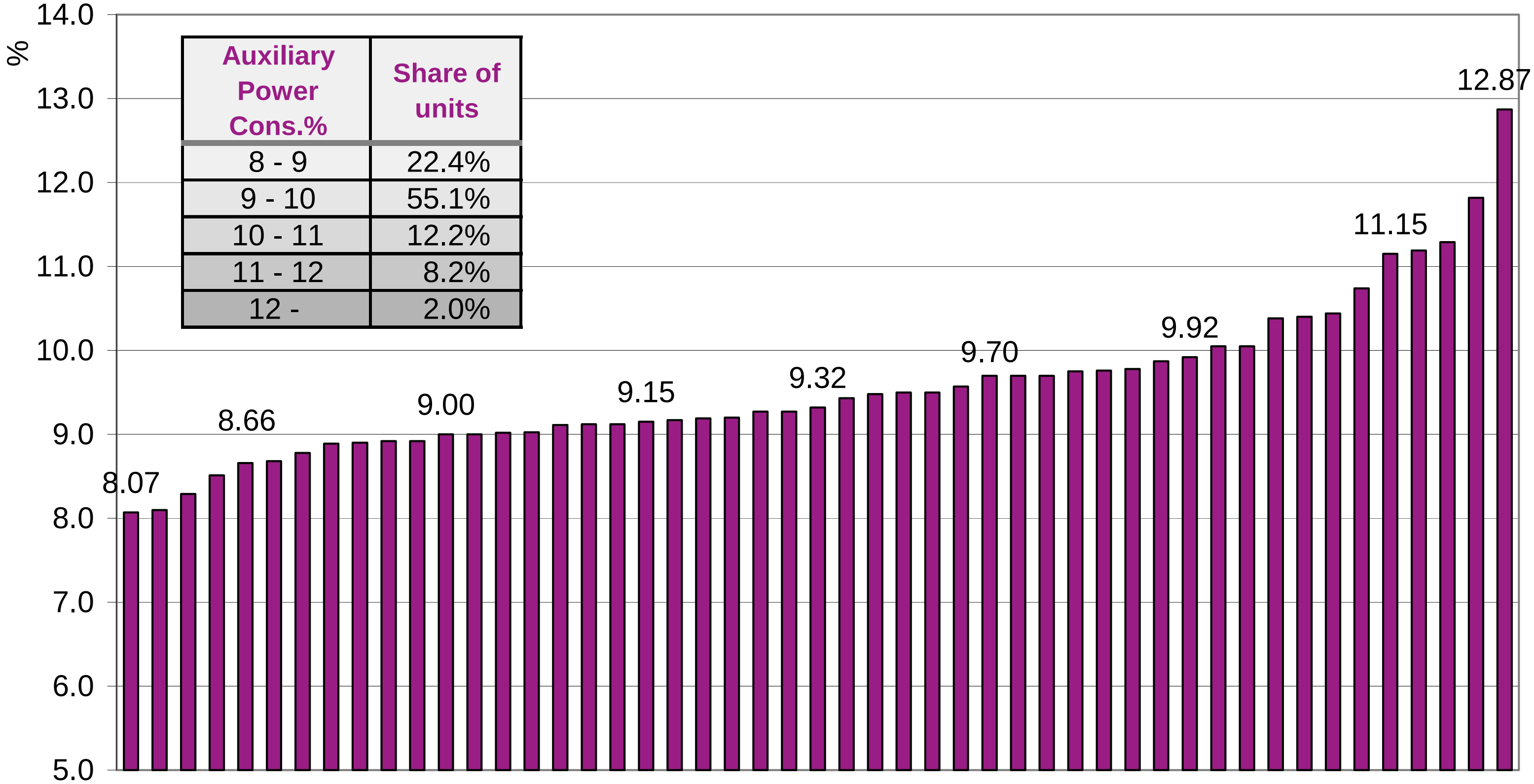


Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

ANNEXURE-30

Operating Auxiliary Consumption of 210 MW capacity units (%)

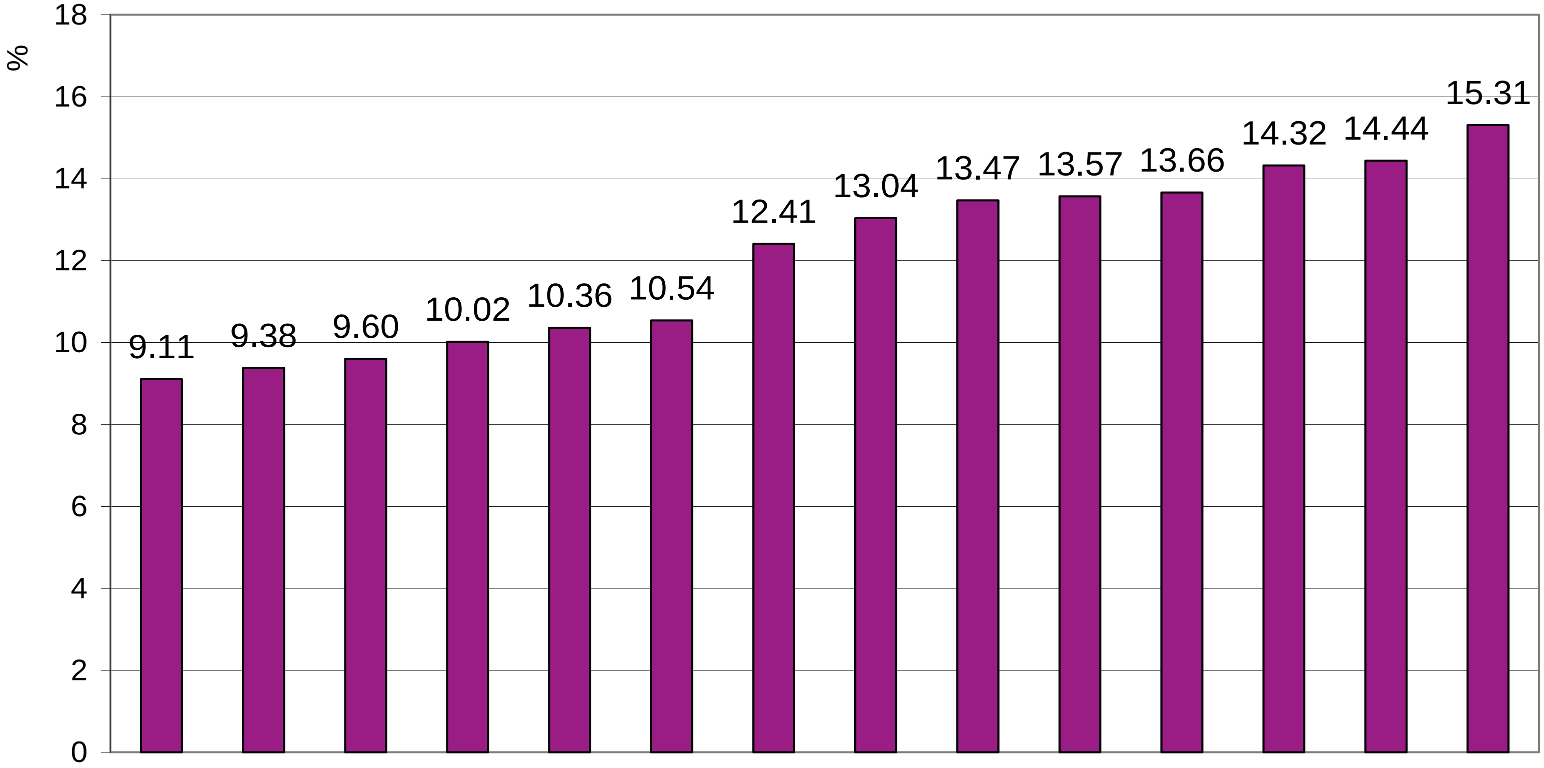
Auxiliary Power Cons.%	Share of units
8 - 9	22.4%
9 - 10	55.1%
10 - 11	12.2%
11 - 12	8.2%
12 -	2.0%



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

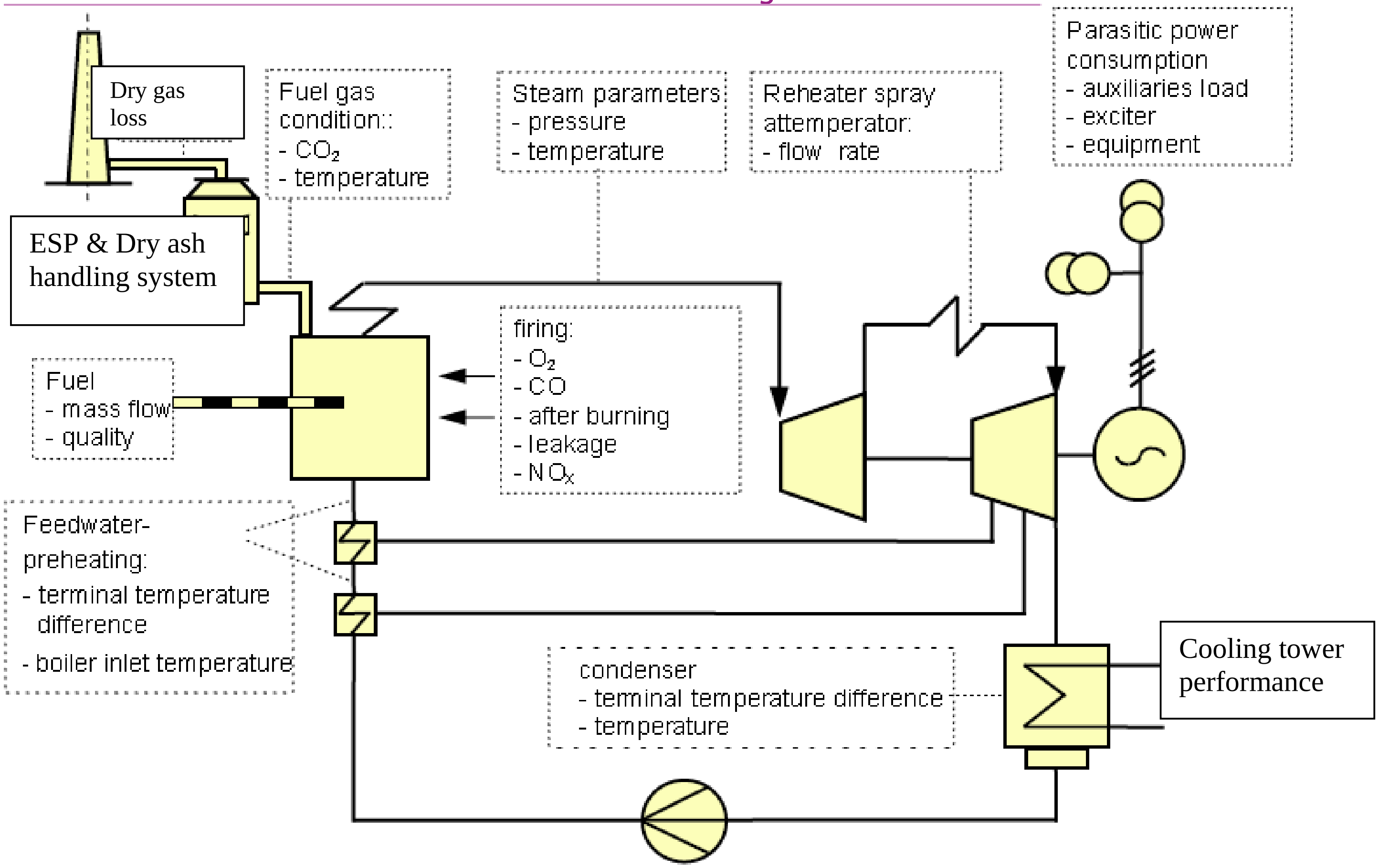
ANNEXURE-3P

Operating Auxiliary Consumption of 110-120 MW capacity units (%)



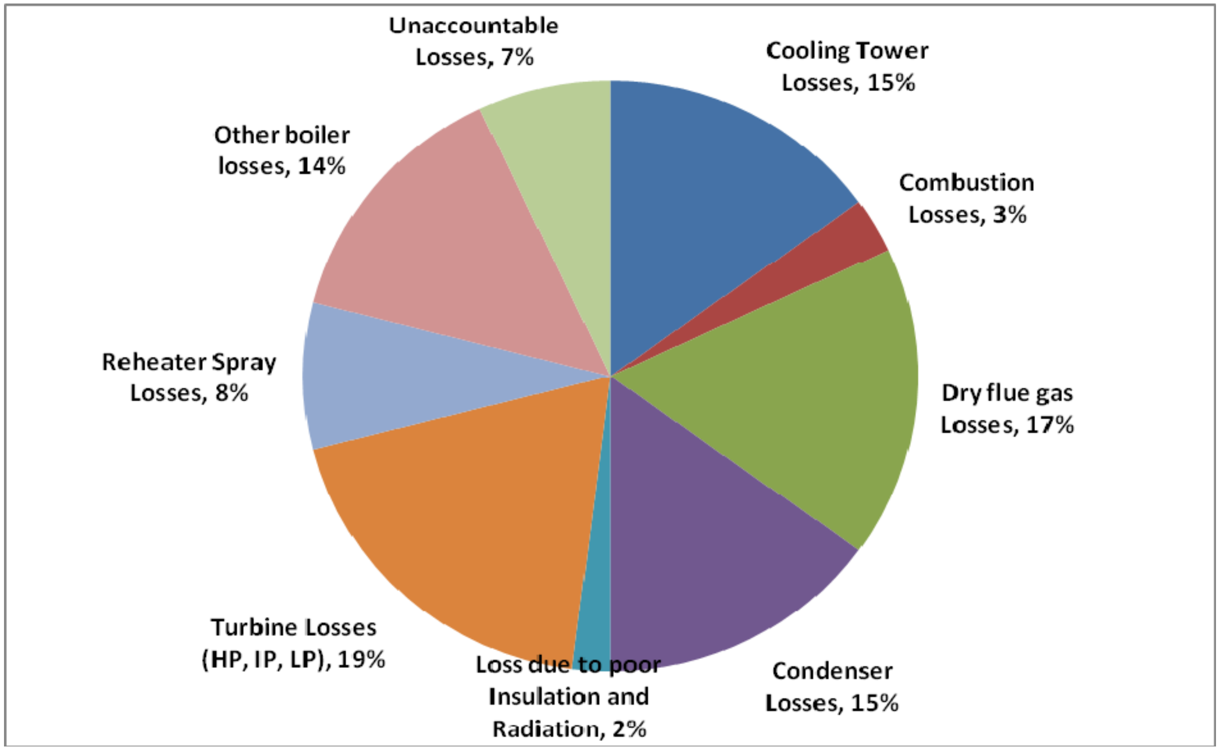
Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model

Performance Monitoring Points



ANNEXURE-4B

Section wise Unit Heat rate losses in a particular unit



Note: Observations/analysis presented in the table are based on the parameters at the time of Mapping Studies and simulated by model