Chapter 3

Description of Design Process

3.1 Introduction

This Chapter has an intention to review the power plant process of the case study, which is Krabi Thermal Power Plant. Firstly, the background of the case study will be presented. Then the power plant process of the case study will be explained in the details. The source of the information, which is used to perform this chapter come from the concept design for Krabi Thermal power plant of the Electricity Generating Authority of Thailand.

3.2 Background of Case Study

Krabi Thermal Power Plant is the new power plant project of the Electricity Generating Authority of Thailand (EGAT). It locates in Krabi Province 800 kilometers to the south from Bangkok. Krabi Thermal Power Plant is built to serve the high growth of the electricity demand in the southern part of the country.

During the constant high growth demand of the electricity during 1992 to 1998, EAGT planned to build the new power plant to serve the electricity demand of the country. So EGAT planned to build Krabi Thermal Power Plant Project to serve the electricity demand of the southern part of the country as state in the previous paragraph. Krabi Thermal Power Plant Project will be consist 2 units of 300 MW thermal power plant. EGAT plan to synchronize the first unit of Krabi Thermal Power Plant Project on January 2000 and the second unit on March 2002.

In 1990 to 1995, the reliability & availability of the power plant of EGAT was the most important topic to discuss during the engineering phase for the new power plant project. Krabi thermal power plant is a new power plant project of EGAT. EGAT has started to do the engineering work for this project since the early of 1998. The engineering work for Krabi thermal power plant consists of civil engineering, mechanical engineering, electrical engineering, control & instrumentation system engineering and project management. EGAT Engineering Business did all of these engineering works.

Krabi Thermal Power Plant Project consists of 2*300 MW Oil-fired Thermal Power Plant. Each unit is based upon one steam driven turbine-generator set, one steam generator and all auxiliary equipment need for the conversion of fuel oil to electricity. Auxiliary system include fuel oil handling and storage facilities, water supply and treatment facilities, air pollution control equipment, ash storage and handing facilities.

The steam generator will be designed to fire No. 6 (heavy) fuel oil. No.2 (distillate) oil will be use for igniter fuel. The cooling tower will be used for condenser cooling. Cooling tower makeup will receive brackish water from Pakasai River. A wet limestone flue gas desulfurization system will be provided to clean up the flue gas discharged to the environment.

The assumed guaranteed generator output is 300 MW each. Based on an assumed auxiliary load of 6.5 percent of gross generation, the net plan output is estimated to be 280.50 MW. The estimated net plant heat rate at 100 percent load for oil firing is 9,876 kJ/kWh.

3.3 Electricity Generation Processes of Krabi Thermal Power Plant

3.3.1 Turbine Generation System

The steam turbine generation system will convert the thermal energy of the steam to mechanical energy required to drive the generator. The steam turbine will be a single shaft, 3,000 rpm, tandem compound, reheat, condensing machine. The primary steam path will be as follows. High-pressure steam will flow from the Main Steam System through the main steam stop valve and control valves into the high-pressure turbine. The steam will flow through the high-pressure turbine and discharge into the reheat section of the boiler. The hot reheat steam will flow through the intermediate-pressure turbine and discharge to the crossover piping to the low-pressure turbines.

After passing through the low-pressure turbines, the steam flow will exhaust downward into the condensers. Steam will be extracted at seven points for regenerative feedwater heating. The generation will be a hydrogen-cooled, 2-pole, 50 Hz, synchronous machine which converts the mechanical energy of the steam turbine into three-phase electrical energy to be transmitted to the power grid and the balance-of-plant equipment. The generator will provide auxiliary power to the steam turbine components through the associated electrical equipment.

The major components of Steam Turbine-Generator System are the following:

- Steam Turbine
- Generator and Electrical Equipment
- Turbine Control and Instrument

Steam Turbine

The steam turbine will provide the means of converting the thermal energy of the steam to the mechanical energy required to drive the steam turbine generator. The steam turbine will have a high-pressure/intermediate-pressure section and a condensing low-pressure section. Appearance and acoustical insulation and lagging with adequate access doors for in-service inspection and maintenance will enclose the steam turbine and associated valves and piping located above the operating floor level. The lagging also will complete enclose the floor around the steam turbine. The turning gear will be an automatic disengaging motor-driven type.

The high-pressure steam turbine will be designed for rated throttle conditions of 2 bars absolute and 538 degree C. The intermediate-pressure turbine will be designed to admit reheat steam at 35.8 bars absolute and 538 degree C. The steam turbine nameplate rating guaranteed by manufacturer will be approximately 3,000 rpm, 161 bars absolute rated throttle pressure.

Generator and Electrical Equipment

The generator will convert the shaft mechanical energy of the steam turbine into three-phase electrical energy in the generator stator. The electrical equipment will transmit electric power to the grid and to the balance-of-plant equipment, in addition to providing auxiliary electric power to steam turbine components. The electrical equipment also will provide protective and regulation functions.

The generator and electrical equipment will consist of, as a minimum, the following components:

- Generator.
- Static or brushless excitation system.
- Neutral grounding equipment.
- Surge protection and potential transformer equipment.
- Metering and relaying.

- Bushing-type current transformer suitable for relaying and metering service.
- Wiring and terminal boards.
- All other electrical equipment as required to provide a complete unit.

The generator will be a hydrogen-cooled, 23 kV, 2-pole, 50 Hz, 3,000 rpm synchronous machine. Rated output of the generator will be selected according to the maximum output of the steam turbine, expected rated data 353 MVA at rated power factor 0.85 corresponding to 300 MW electric active power delivered at the generator terminals. Lubrication for the generator will be supplied from the steam turbine lubrication oil system. The stator and rotor will both be provided with Class F insulation with a Class B temperature rise. Stator RTD temperature detectors will be furnished with the generator.

The excitation system will be either a brushless or static excitation system. The neutral grounding transformer and secondary resistor in combination will be used to limit generator neutral ground current and over voltage on a phase-to-ground fault at the generator line terminals. Generator neutral ground current sensing will also be a function of the neutral unit.

Turbine Control and Instrumentation

The turbine control and instrumentation system will sense, compute, record and display pertinent turbine operational information for use by plant operators and control systems. It will provide remote manual and automatic control of turbine operation over its full operational range and also provided protection to turbine against potentially dangerous operating conditions.

The turbine control and instrumentation system will include the following major component:

- Electrohydraulic control subsystem (EHC).
- Emergency trip subsystem (ETS).
- Turbine supervisory instrument subsystem (TSI).
- Turbine monitoring and control subsystem (TMC).

The turbine EHC subsystem will be a microprocessor-based system that will sense turbine speed, steam flow, and generator load to provide automatic control of turbine speed, acceleration, and load over the entire turbine operating range and to limit these parameters to minimize turbine rotor thermal stress. The ETS subsystem will protect the turbine system from out-of-time operating parameters by initiating automatic trips. The TSI subsystem will sense and indicate turbine temperature and vibration parameters, provide alarms for out-of-tolerance parameters, and initiate turbine trips through the ETS subsystem. The TMC subsystem will provide monitoring function for the turbine and generator and present this information to the operators through a CRT and printer. The TMC will also provide an automated turbine startup program.

An attempt will be made to integrate the turbine generator manufacturer's operator interface through the Distributed Control and Information System (DCIS). This will require redundant data highway links between turbine control system and the DCIS. The intent will be to minimize the number of turbine operation interface sub panels and to provide as much as turbine control as possible through the DCIS operator interface.

3.3.2 Turbine Seals and Drains System

The turbine seals and drains system will provide steam to the high-pressure, intermediate-pressure, and low-pressure turbine labyrinth seals. The sealing system will prevent atmospheric air from leaking into the turbine through the turbine rotor gland seals. The sealing system will also prevent steam from leaking out into the plant operating area through the turbine rotor gland seals.

Gland sealing steam will be supplied to the turbines by extractions from the main steam header, one of the cold reheat steam headers, and the auxiliary steam line. The auxiliary steam line ties into the cold reheat line before connecting into the Turbine Seals and Drains System. The seal steam pressure will be regurated by a control valve station in both the main steam line and the cold reheat steam line to the Turbine Seals and Drains System.

Any excess steam will spill automatically to Low – Pressure Feedwater Heater to maintain the seal steam manifold pressure. If a high-high water level exists in the heater shell, then the excess seal steam will automatically spill to the condenser.

A continuous drain with an orifice plate, a trap, or both will be provided at the low points of the steam lines and the seal steam manifold. The drainlines will be routed to either the condenser or the boiler blowdown header.

A desuperheater will be located in the seal steam line to the low-pressure turbines. The desuperheater will lower the steam temperature to prevent possible distortion of the gland seals and damage to the turbine rotor. The Condensate System will supply the desuperheating spray water through a connection near the condensate pump discharge. The seal steam supply pips in the condenser will be insulated to prevent excessive cooling the seal steam.

The seal steam, along with the air, which has leaked into the gland seals, will leave the outer glands of the high-pressure and intermediate-pressure turbine, low-pressure turbines and will be routed to the gland steam condenser. The seal steam will then be condensed by the condensate flowing through the tubes of the gland steam condenser. The condensed steam will return to the cycle via a loop seal to the condenser. The air and any other noncondensable gases liberated from the seal steam during the condensation process will exhaust to the atmosphere by the gland condenser blowers.

The Turbine Seals and Drains System will be protected in the event of an overpressure situation by safety valves. The safety valve are located on the seal steam manifold. A motor-operated condenser vacuum breaker valve will be provided on the condenser to break the condenser vacuum when the unit is shutdown.

Condensate from the discharge of the condensate pumps will be supplied to the low-pressure turbine exhaust hood sprays to prevent overheating of the low-pressure turbine casings during turbine startup. Condensate from the condensate storage tank located on the deaerator floor will be supplied to the steam packings of several valves in Turbine Seals and Drains System and in the low-Pressure Extraction System. The seal water will prevent steam from leaking through the valve stem packings.

An emergency spray water flow will be supplied to the gland condenser shell from the condensate pump discharge header. A manually operated valve in the emergency spray waterline normally will be closed. The emergency spray water will be required only during abnormal periods when the condense the incoming turbine gland steam and leak off steam.

The major components of the Turbine Seals and Drains System will be the seal steam desuperheater and the gland condenser.

Seal Steam Desuperheater

The seal steam desuperheater will be the condensate spray type and will control the temperature of the seal steam to the low-pressure turbines.

Gland Condenser

The gland condenser will be the shell and tube type with two exhausting blowers. The seal steam from the turbines will pass through the shell and will be condensed by the condensate flowing through the tubes.

3.3.3 Turbine Lube Oil System and Control Oil System

Turbine Lube Oil System

The Turbine Lube Oil System will consist of lube oil storage equipment, filtering equipment, and pumping equipment.Turbine lube oil will be pumped from the turbine lube oil reservoir to the turbine bearing by the turbine jacking lube oil pumps and by the lube oil pumps located in the turbine lube oil reservoir. The turbine lube oil reservior will also contain a vapor extractor, a mist eliminator, a sight overflow, and two lube oil coolers.

The turbine lube oil vapor extractor will draw off the air that has accumulate in the turbine lube oil reservoir and vent the air into the atmosphere through the turbine lube oil mist eliminator. The turbine lube oil mist eliminator will remove any oil mist or oil droplets entrained in the airstream. The accumulated oil will be cycled back to the precipitation compartment of the turbine lube oil conditioner.

The two turbine lube oil coolers will both be full capacity. The turbine lube oil will flow from the turbine lube oil reservoir, through the shell of the in-service lube oil cooler, and will then be routed to the turbine bearings. The turbine lube oil will be cooled by the closed cycle cooling water flowing through the tubes of the turbine lube oil cooler. The turbine lube oil may be routed through either turbine lube oil cooler by manually operating the turbine lube oil cooler diverting valve.

The turbine lube oil reservoir will supply turbine lube oil to the turbine lube oil conditioner by way of the sight overflow. The lube oil will flow into the conditioner by gravity where the lube oil will be filtered in three stages, removing solid particles and water. The lube oil will be pumped from the storage compartment of the turbine lube oil conditioner, through the third-stage filter (cartridge filter), and will be returned to the turbine lube oil reservoir.

The turbine lube oil conditioner vapor extractor will remove any air that may be have accumulated in the turbine lube oil conditioner. During normal operation, the turbine lube oil conditioner will filter approximately 20 percent of the turbine lube oil in circulation each hour. The turbine lube oil reservoir also will supply turbine lube oil to the turbine lube oil centrifuge by gravity. The turbine lube oil centrifuge will consist of a feed pump, two electric heaters, and a centrifuge. The centrifuge will remove the solid particles and water from the turbine lube oil by centrifuge action.

Turbine Lube Oil Reservoir

An all welded carbon steel tank will serve as the reservoir for the turbine lube oil in use. The turbine auxiliary lube oil pump, the turbine turning gear lube oil pump, the turbine emergency lube oil pump, and the turbine lube oil vapor extractor will be mounted on the tank. The turbine lube oil reservoir will be equipped with two level switches, a temperature element, a temperature switch, a manhole, and a sight overflow.

Turbine Lube Oil Coolers

Two full capacity lube oil coolers will be provided adjacent to the turbine lube oil reservoir. The coolers will be connected to the turbine lube oil reservoir by a six-port diverting valve. This valve will be manually operated and will be used to select the in-service lube oil cooler. The turbine lube oil coolers will be the shell and tube type with the turbine lube oil flowing through the shell. The cooling medium will be closed cycle cooling water, which flows through the tubes. The shell and channel for the turbine tube lube oil coolers will be constructed of carbon steel.

Turbine Lube Oil Storage Tank

The turbine lube oil storage tank will be of all welded carbon steel construction and will be divided into two separate compartments: the turbine lube oil dump tank and the clean turbine lube oil storage tank. Each tank compartment will have a fill connection, a floating pump suction outlet, a deep suction outlet, a sample outlet, a drain connection, a vent connection, a clean out connection, a manhole, and three pairs of gauge glass connections. The turbine lube oil reservoir will be mounted directly on the top of the storage tank. Either tank compartment will be filled from the turbine lube oil reservoir or from the manual fill nozzle. The deep suction connection will be used during cleaning of the tank.

Turbine Lube Oil Conditioner

The three-stage filtering unit will have the capacity to filter 20 percent of the normal turbine lube oil reservoir storage capacity per hour. Water and particles are removed with an effectiveness of 1 micron. The turbine lube oil conditioner is constructed of carbon steel.

The turbine lube oil conditioner-circulating pump will be a positive displacement, rotary gear-type pump mounted on the top of the turbine lube oil conditioner. The pump will draw the lube oil out of the storage compartment and pump it through the cartridge filter to the turbine lube oil reservoir.

The turbine lube oil vapor extractor will be a multi-blade centrifugal fan mounted on top of the turbine lube oil conditioner. The turbine lube oil conditioner will be equipped with two level switches, three gauge glasses, compartment acess doors, and a drip pan.

Turbine Lube Oil Centrifuge

The turbine lube oil centrifuge will be a disk bowl-type centrifuge with stainless steel and bronze components. The frame will be made from cast iron with a vapor-proof hinged cover.

A positive displacement rotary screw-type feed pump will be integral to the centrifuge unit. The feed pump will circulate the influent through the electric heaters and into the centrifuge bowl. One inside the centrifuge bowl, the solid particles and water will be separated from the turbine lube oil by centrifugal action. The centripetal discharge pump, which will be integral with the centrifuge bowl, will then pump the purified turbine lube oil back to the turbine lube oil reservoir. The solid particles and water will be drained by gravity to a floor drain. Two electric heaters will be provided to heat the unpurified turbine lube oil to aid in the separation process.

Turbine Lube Oil Transfer Pump

The turbine lube oil transfer pump will transfer turbine lube oil from either compartment of the turbine lube oil storage tank to either the turbine lube oil reservoir, the turbine lube oil conditioner, or the turbine lube oil centrifuge. The transfer pump will be the positive displacement, rotary screw type.

Turbine Control Oil System

The turbine control oil fluid shall be free resistance control oil. The system shall include two 100% capacity of hydraulic pumps. The turbine control oil system shall be completely separate from the turbine lube oil system. The redundant control oil system heat exchangers shall be the U-tube design with a double tube sheet and a leak off between the tube sheets. The cooling capacity shall be sufficient to adequately cool the control oil when both control oil pumps are in operation. The closed cycle cooling water shall be used to cool the control oil.

3.3.4 Generator Cooling and Purging System

The Generator Cooling and Purging System will supply hydrogen for generator cooling and carbon dioxide for generator purging. Hydrogen and carbon dioxide will be uniformly distributed to the various compartments of the inner cooled generator by manifolds located in the top and bottom of the generator housing.

The major components of the Generator Cooling and Purging System will be the following:

- Hydrogen supply unit
- Carbon dioxide supply unit
- Hydrogen gas dryer
- Water detectors
- Hydrogen control panel

Hydrogen Supply Unit

The hydrogen supply unit will consists of eight hydrogen bottles, manifold, filter, bottle pressure switch with low-pressure alarm, pressure regulator, supply pressure indicator, and relief valve. The hydrogen bottles will be connected to the manifold by flexible hoses.

Carbon Dioxide Supply Unit

The carbon dioxide supply unit will consists of eight carbon dioxide bottles, manifold, supply pressure indicator, and relief valve. The carbon dioxide bottles will be connected to manifold by flexible hoses.

Hydrogen Gas Dryer

Water will be removed from the hydrogen or carbon dioxide gas in the generator by circulating the gas through the hydrogen gas dryer. The dryer will contain activated alumina absorbent material. The moisture-laden absorbent will be dried and reused.

Water Detectors

Two water detectors, one located under the generator housing and one located under the generator leads, will be provided to detect condensed or leaked water. The detectors will contain float-operated mercury switches in small housings.

Hydrogen Control Panel

The hydrogen control panel will be designed to facilitate operation and maintenance of the Generator Cooling and Purging System. The panel will contain a hydrogen and carbon dioxide purity meter, purity meter blower, and dual generator blower pressure and generator hydrogen pressure meter.

3.3.5 Condenser Air Extraction System

The Condenser Air Extraction System will remove the noncondensable gases from the shell side of the condensers. If the noncondensable gases are not removed, they will blanket the condenser tubes, reducing the heat transfer capacity of the condensers. The noncondensable gases will be removed from the condenser shells, which will operate below atmospheric pressure, by the condenser exhauster units and will be discharged to the atmosphere. Two condenser exhauster units will serve the condenser during hogging operation.

During holding operation one condenser exhauster unit shall be put into operation. The hogging time shall not more than 30 minutes from atmosphere pressure to 0.3 bar. The separator/silencers will be furnished with check valves, high-level alarm level switches, low level seal water makeup solenoid valves, vents, drains, and overflows. Seal water makeup to the separators will be supplied from the condensate storage tank. The seal water pumps will be the centrifugal type. The seal water heat exchangers will be the single pass counterflow type. Cooling water for the seal water heat exchanges will be supplied from the Circulating Water System.

3.3.6 Steam Generation System

The Steam Generator System will consists of the boiler and related equipment, including two regenerative-type air heaters, combustion air wind boxes with burners, ductwork, piping, and valves.

Design conditions for the steam generator system will be as follows:

Steam flow from superheater, kg/s	875
Steam pressure at superheater outlet, bars	162
Steam temperature at superheater outlet, degree C	538
Steam temperature at reheater outlet, degree C	538
Ambient air temperature, degree C	30
Air heater gas outlet temperature (uncorrected), degree C	150

The Steam Generator System will sustain operation at all loads from startup to the maximum capability of the unit. Prolong low load operation firing the primary fuel will be possible without the need for light oil igniters to stabilize firing. The steam generator will maintain design superheat and reheat steam temperatures from its control point rating to the maximum capacity of the unit within $\pm$ 5 degree C of the design valve listed in the steam generator specifications. Burners, ducts and other equipment will be designed to permit steam generator operation with excess airflow of up to 30 percent.

The steam generator will be a drum type, control circulation, balanced draft, tangentially fired, reheat unit capable of burning No.6 fuel oil. It will be equipped with light fuel oil igniters, with one level of warm-up guns. The oil burners will be steam-atomized type and will be low steam consumption.

Combustion air will be supplied by two 60 percent axial flow-type, motor-driven forced draft fans. Each fan will be equipped with blade position equipment. Combustion airflow measurement will be accomplished by measuring the flue gas differential pressure across the economizer. Individual airflow and pressure differential will also be measured.

Each corner of burners will have a compartment wind box having fuel and air nozzles arranged vertically and serving each elevation of igniters, warm-up guns and oil burners. Modulating dampers will be provided at each wind box for control of fuel air, secondary air, and over fire air.

Superheat steam temperature control will be accomplished using water spary desuperheating. Reheat steam temperature control will be controlled primarily by tilting boiler. Two flow controlled spray attemperators will be provided at the reheater inlet for use as a backup or emergency system to maintain reheat temperature during transients or abnormal operating conditions. Spray flow will be controlled by two redundant pneumatic flow control valves.

Two 60 percent capacity, axial flow induced draft fans will be used to maintain furnace draft and will cover flue gas pressure drop in FGD including connecting ductworks up to the stack. The fans will be driven by constant speed drive motors through variable speed hydraulic couplings. Each fan will be equipped with two parallel blade discharge damper mounted in series on the fan discharge flange and a parallel blade inlet damper.

3.3.7 Boiler Combustion Air

The Boiler Combustion Air System will include the equipment and ductwork to provide the air required for combustion of the fuel, flame scanner, and gas recirculation seal air; air for the igniters; and the associated controls and instrumentation. Outside air will be taken in by the forced draft fans and will flow through the air preheat coils and regenerative air heaters to the boiler wind box. The forced draft fan will be equipped with an inlet silencer to reduce sound levels. The air preheat oil will use hot water from the Condensate System to maintain a preset average air-in, gas-out temperature of 120 degree C (248 degree F). The air heaters will use hot gas from the economizer to further heat the air. The heated air will be mounted at the burner wind box by the fuel air dampers and auxiliary air dampers before it enters the furnace.

A crossover duct will be installed between the forced draft fan discharges upstream of the air preheat coil to allow operation of one fan while maintaining airflow through both air heaters and to balance the pressure between each duct. The crossover duct also will allow operation with an air heater or induced draft fan out of service.

Other components of the system will include the igniter air booster fans, the ac flame scanner cooling fan, and dc flame scanner emergency cooling fans. The igniter air booster fans will provide combustion air for the No.2 fuel oil igniters. The ac flame scanner cooling fans will maintain a constant airflow to cool the flame scanner-viewing lens. In the event of loss of auxiliary power, the dc flame scanner emergency cooling fans will automatically go into service to back up the ac flame scanner cooling fans.

The major components in the Boiler Combustion Air System will be as follow:

- Two Forced Draft Fans
- Two Air Heaters
- Two Air Pre-Heater Coils
- Two Igniter Air Booster Fans
- Two AC Flame Scanner Cooling Fans
- Two AC Flame Scanner Emergency Cooling Fans
- Two Gas Recirculation Fans

Forced Draft Fan

The two forced draft fans will be half-capacity, axial flow, adjustable pitch, single-stage fans complete with inlet sound trunks, outlet isolation dampers, and blade pitch control. Each fan will have a lube and control oil unit, which will consist of pumps, controls, and oil-to-water heat exchangers.

Air Heaters

Two vertical shaft, rotary, regenerative air heaters will be provided. Each heater will consist of metal plates grouped in baskets, which are arranged in sectors. The sectors will be supported from a center shaft. The basket elements in the intermediate and will be corrosion-resistant, low alloy steel; the cold-end elements will be enameled steel. Hot-end elements will be mild steel. Seals constructed of corrosion-resistant low alloy steel will prevent gas and air leakage around the rotor. Electric motors normally will drive the air heaters, and air-powered motors will drive the air heater in the event of a power failure. A separate lubrication system will be supplied for the support and guide baring, complete with pump filters and water-to-oil heat exchangers, which will be closed cycle cooling water to maintain required temperatures. Stationary water washing nozzle will be provided for the cold and hot ends, in addition to a twin port steam soot blowing device.

Igniter Air Booster Fans

Two full capacity centrifugal backward curved blade fans will be provided. The fans will take suction from the forced draft fan discharge.

AC and DC Flame Scanner Cooling Fans

Two full capacity ac flame scanner cooling fans and two full capacity dc flame scanner emergency cooling fans will be provided. The fans will be the centrifugal radial impeller type. These fans will take suction from the discharge of the forced draft fans or from the atmosphere.

3.3.8 Induced Draft System

The Inducted Draft System will remove the products of combustion from the boiler furnace. The hot gas will flow through the regenerative air heater, the FGD system, and the connecting gas ducts to the stack. The system will consist of two air heaters, two induced draft fans, flue gas ducts, stack and controls.

Two 60% Induced Draft Fans, axial flow fans will be the horizontal shaft, adjustable pitch, single stage fans complete with silencers, inlet and outlet isolation dampers and blade pitch control. Each fan will have a control lube oil unit, which consist of pumps, controls and oil-to-water heat exchangers.

3.3.9 Air Preheat Water System

The Air Preheat Water System will circulate hot water from the deaerator storage tank, through the air preheat coils, back to the deaerator. Two air preheat coils, one located in each forced draft fan discharge, will preheat the combustion air before the combustion air enters the regenerative air heaters.

The major components of the Air Preheat Water System will be the three air preheat water pumps and the two air preheat coil.

Air Preheat Water Pumps

The three half-capacity air preheat water pumps will be centerline mounted, vertically split pumps specifically designed for hot water service.

Air Preheat Coils

The two air preheat coils will be the finned tube with copper fins and stainless steel tubes. The air preheat coils will be designed to heat the combustion air to a temperature which can maintain the average of the air heater combustion air inlet temperature and the air heater uncorrected gas outlet temperature at 120 degree C (248 degree F). The two air preheat coils will use identical removable tube cores to minimize spare parts requirements.

3.3.10 Boiler Circulating Water System

The Boiler Circulating Water System will maintain adequate boiler water circulation through the boiler tubes. Boiler water from the upper drum will descend through downcomer to the boiler circulating water pump suction header. Three (3) 50% capacity boiler circulating water pumps will take suction from this header and discharge into lower drum.

Boiler Circulating Water Pumps

Each boiler circulating water pump set will consist of a pump, a submersible type induction motor, and a thermal barrier located between the pump and the motor or seal water control system. Boiler water will flow axially into the pump through a suction nozzle. Boiler water will flow radically from the pump through two discharge nozzles.

The submersible, three-phase, squirrel-cage motor will have plastic insulated stator windings. The motor will be subjected to the same system pressure, as is the pump. The system pressure will transmit by the gap between the shaft and the thermal barrier.

Boiler Circulating Water Pump Motor Heat Exchanges

The Boiler Circulating Water Pump Motor Heat Exchangers will remove the heat generated in the motor and the bearing during operation of the pump set. The shaft of each pump set will be guided and supported by two water-lubricated radial journal bearings and one water-lubricated thrust bearing.

Cooling water will be supplied to the heat exchange from the Closed Cycle Cooling Water System. The water, which circulates through the motor, will be supplied from the condensate pump discharge header.

3.3.11 Soot Blowing System

The Soot Blowing System will use auxiliary steam to remove ash from the heat transfer surfaces of the boiler and air heaters. The steam pressure will be reduced to a blowing pressure of 13.7 bars before the steam is supplied to boiler soot blowers and air heater soot blowers.

Boiler Soot Blowers

The boiler soot blowers will be long retractable soot blowers.

Air Heater Soot Blowers

The air heater soot blowers will be single nozzle, twin port cleaning devices.

3.3.12 Boiler Vents and Drains System

The Boiler Vents and Drains System will consist of the vents and drains required during startup and shutdown, the continuous drum blowdown, the drum safety valves and the drum instrumentation.

The vents and drains will be opened during startup to allow complete purging of the boiler with steam. The vents and drains will be closed when the air and other noncondensable gases are purged from the boiler and the boiler components have been heated sufficiently to eliminate condensation. With the exception of the drum continuous blowdown, all vents and drains will be closed during normal operation.

Vents will be safely routed to atmosphere. Drains will be collected in the boiler blowdown tank where flashed steam is vented to the atmosphere. Nitrogen blanking of the boiler will be required when the unit is shutdown and cooled or when the unit is drained. Nitrogen will be supplied through the vents as required to prevent introduction of oxygen and other contaminants into the boiler.

The drum continuous blowdown will maintain the blowdown flow necessary to limit to acceptable levels the amount of suspended solids and silica in the boiler. During normal operation, the blowdown will flow through two angle blowdown valves into the continuous blowdown flash tank. Part of the blowdown will flash to steam and flow from the flash tank to the deaerator. The rest of the blowdown will collect in the flash tank and flow through the continuous blowdown heat exchanger to the solids contact units. During startup and shutdown, the blowdown will be valved to bypass the flash tank and flow into the boiler blowdown. Tank.

The major components of the Boiler Vents and Drains System will be the following:

- Continuous blowdown flash tank
- Continuous blowdown heat exchanger
- Boiler blowdown tank
- Drum safety valves

Continuous Blowdown Flash Tank

The continuous blowdown flash tank will be a vertical cylindrical tank. A safefty valve will be located on the flash tank steam outlet to the deaerator to relieve excess pressure.

Continuous Blowdown Heat Exchanger

The single pass, horizontal continuous blowdown heat exchanger will be designed for condensate flow on the tube side and blowdown flow on the shell side. A safety valve will be located on the heat exchanger shell to protect it from over pressure.

Boiler Blowdown Tank

The vertical, cylindrical boiler blowdown tank will be located on the ground floor.

Drum Safety Valves

Drum safety valve, designed for venting saturated steam to atmosphere, will be provided for boiler protection in case of overpressure. Three of the safety valves will be located on the West End of the drum. The other three safety valves will be located on the East End of the drum.

The safety valve vent piping will consist of safety valve vent stacks, steam vent piping from safety valve body vents, and drip pans. The safety valve vent stacks will be the open, aspirating type discharging into the atmosphere. The steam vents from the safety valve bodies will be piped to allow for safety valve movement and discharge into the vent stacks. Drip pans will be provided at the inlet of the vent stacks to collect condensate drainage.

3.3.13 Air Heater Wash Water System

The Air Heater Wash Water System will supply wash water to the air heaters from the service water main header. Wash water will supply to both the hot end and cold end of each air heater. The wash water will be drained to trenches through drain connection located on the inlet and outlet ducts of each air heater. Control of the Air Heater Wash Water System will be by opening and closing manual valves to start and stop the flow of wash water.

3.3.14 Flue Gas Treatment

The flue gases discharged from the steam generator will pass through the Flue Gas Desulfurization (FGD) unit. The FGD process selected is a wet limestone scrubbing process which removes 80% of the SO_2 from the flue gas.

The FGD system consists of the following main subsystems:

- Sulfur Dioxide Absorption
- Reagent Preparation
- Waste Product De-watering

Sulfur Dioxide Absorption

Flue gas exiting the boiler passes through a regenerative type heat exchanger where it re-heats the clean flue gas upstream of the stack. The cooled flue gas is then contacted with the limestone slurry at the top of the scrubber. The flue gas is simultaneously quenched, particulate removed and desulfurized in the absorber. Absorbed SO_2 is oxidized by air in the absorber tank forming sulfuric acid (H_2SO_4). Limestone ($CaCO_3$) fed into the tanks neutralizes the H_2SO_4 and gypsum ($CaCO_3$ 2 H_2O) is formed. The gypsum slurry is dewatered and sent to disposal.

Reagent Preparation

Crushed limestone transported either by trucks, is unloaded via an unloading and reclaim hopper and a conveyor system and stored into a dead storage area, as shown on figure 6 or into a live storage silo. A stacking and reclaim system is provided for the dead storage area. From the day storage silo the crushed limestone is transported by bucket elevator to a surge hopper and from there via a weigh feeding system into the wet grinding mill. The pulverized limestone is classified in a hydroclone type centrifuge.

The fine fraction (overflow) flows to a limestone slurry storage tank while the coarse fraction (underflow) is recycled back to the mill for further grinding. The limestone is fed by a screw feeder into the limestone slurry tank where it is slurried by the proportional addition of process water. From the slurry tank, fresh reagent is pumped into the absorber tank. The absorber pumps take suction from the absorber and recycle the slurry to the spray headers at the top of the tower where it is distributed within the absorber. Based on 80% SO_2 removal efficiency the limestone consumption is estimated to be 6.54 tones/hour for two units when operating at full load.

Waste Product Dewatering

The FGD waste product cristalized gypsum has to be removed from the recirculating limestone slurry. An absorber slurry bleed stream at 10-12% wt. Solids is pumped to the wastewater dewatering system to separate the solids for disposal from the liquid which is returned to the limestone slurry system. The slurry is processed through a hydroclone system where is concentrated to about 50% wt. Solids.

The hydroclone solids containing under flow stream is pumped to vacuum belt filters where the gypsum solids are concentrated to about 80 % by weight. The filtrate is returned to reagent preparation and absorption systems. T he gypsum is removed by a system of conveyors to the on-site waste disposal landfill. Bulldozers are provided in the landfill area for handling the dewatered gypsum product.

3.3.15 Condensate System

Condensate System

The Condensate System will provide the flow path the low-pressure exhaust to the Boiler Feedwater System and provide regenerative feedwater heating. The low-pressure turbine exhaust steam will be condensed in one surface condenser. One surface condenser will be provided for each low-pressure turbine. The condensate will be pumped through the condensate polishing system, the gland condenser or continuous blowdown heat exchanger, and four low-pressure feedwater heaters. After passing through the low-pressure feedwater heater, the condensate will flow through the deaerator and will be collected in the deaerator storage tank.

Regenerative feedwater heating will be provided by the four stages of feedwater heating and deaerator. The primary function of the deaerator will be remove-dissolved oxygen and other noncondensable gases from the condensate. Bypasses will be furnished around the Condensate Polishing System, the gland condenser and continuous blowdown heat exchanger and low-pressure heaters.

The Condensate System will also supply high purity water to the following equipment:

- Sample table for analysis
- Boiler feed pump seal water pumps
- Boiler circulating water pumps
- Ammonia solution tank
- Closed cycle cooling water storage tank
- Low-pressure turbine exhaust hood
- Turbine valves valve stem packing
- Steam drum
- Seal steam desuperheater
- Low-pressure turbine vacuum breaker
- Low pressure bypass desuperheater
- Condensate storage tank
- Cycle chemical feed tanks

The major components of the Condensate System will be the following.

- One surface condenser
- 2*100% condensate pumps
- Low-pressure feedwater heater
- Deaerator

Surface Condenser

The condensers will be two-pass, horizontal surface condensing heat exchangers with integral deaerating hot wells. Divided water boxes will be furnished, consisting of separate water boxes for each half of each condenser shell. The depressed section of the hot well will permit direct horizontal below floor suction piping connection to the condensate pumps.

The condenser tube and tube plate material will be titanium. The primary function of the condenser will be to condense exhaust steam from the low-pressure turbines. In addition, the condenser provides the following.

- A low-pressure collecting point for condensate drains from various systems
- Deaeration of collected condensate
- Short-term storage of condensate

Condensate Pumps

Two 100% capacity, vertical, wet suction, motor-driven condensate pumps will be provided. Each condensate pump and motor will be connected by a variable speed hydraulic coupling to permit deaerator level control by varying the pump speed. The pumps will be arranged for below floor suction from the hot well and above floor discharge.

Low Pressure Feedwater Heaters

Four low pressure heaters consisting each of condensing and drain cooling zone will be installed for regenerative heating of the condensate between the gland steam condenser and feed water storage tank. Extraction steam will be taken from LP part of the turbine. An individual by-pass will be installed on the condensate side of each LP heater. The extraction steam condensate will be drained by cascading to the main condenser. The drain flow will be controlled by means of respective level controls of individual heaters.

Deaerator

The deaerator will be the direct contact spray type with an integral vant condenser. The horizontal cylindrical shell deaerating section will be supported on the horizontal cylindrical shell storage section.

The primary function of the deaerator will be to remove dissolved oxygen in excess of 0.005 cubic centimeter / liter for unit load of 5 percent through 100 percent of rated capacity. Addition deaerator functions will include the following.

- Heat the condensate in the last stage of the Condensate System before it enter the Boiler Feed Water System
- Receive the boiler feed pump re-circulation
- Provide the condensate for air preheat
- Provide the boiler feed pumps with the required suction head
- Receive condensate and retain it in the storage tank

The deaerator shell will be constructed of carbon steel designed for a maximum pressure of 13.8 bars at 205 degree C. The trays and tray support will be fabricated from stainless steel. The deaerating heater will be mounted on the top of the deaerator storage tank. The deaerator storage tank volumn, the deaerator elevation, and the boiler feed pump suction lines will be designed to ensure adequate net positive suction head at the pump suction nozzle during load rejection.

The deaerator storage tank volume will have a storage volume at normal operation level at least corresponding to 15 minutes operation at maximum continuous rating.

Boiler Feedwater System

The Boiler Feedwater System will supply deaerator storage tank to economizer inlet of the steam generator. Before entering the economizer, the feedwater will be heated as it flows through the tubes of high-pressure feedwater heaters. The feedwater will be heated with steam provided by the High-Pressure Extraction System and condensate provided by the Heater Drains System. The feedwater flow and pressure will be controlled over the complete until load range to meet the required load conditions. The 3*50% capacity, motor-driven boiler feed pumps will be provided for the Boiler Feedwater System.

Boiler Feedwater from each boiler feed water pump discharge line will supply spray water to the first-and second-stage superheat desuperheaters. The discharge lines will be combined and then piped through a motor-operated shutoff valve and a flow nozzle to the superheat desuperheaters. Two parallel full capacity control valve stations will be funished with each of the four first-stage superheat desuperheaters and with each of the two second-stage superheat desuperheaters. Desuperheating spray water for the reheat desuperheaters will be provided from the boiler feed pumps discharges header. A line will branch off the discharge heater and go through a motor-operated shutoff valve and a flow nozzle to the reheat desuperheaters. Two parallel, full capacity, control, control valve stations will be furnished with each of the two reheat desuperheaters.

A motor-operated boiler feedwater flow control orifice valve will be installed in the boiler feedwater piping near the economizer inlet. The valve orifice will be lowered into the boiler feedwater flow steam at loads less than approximately 60 percent of unit load. The orifice will provide an additional pressure differential between the steam flow and the desuperheat spray flows at the first-and second-stage superheat desuperheaters. At unit loads above approximately 60 percent, the pressure differential between the steam flow and the desuperheat spary flow will be sufficiently high so that the calve orifice will be pulled out of the boiler feedwater flow steam, providing an unobstructed flow path through the valve.

The discharge line for each of the boiler feed pumps will contain a motor-operated shutoff valve, a power-assisted check valve, and a flow nozzle. Each boiler feed pump will be provided with an individual recirculation line to the deaerator storage tank to maintain a minimum flow through the boiler feed pumps. Each recirculation line will contain a control valve and a flow-measuring orifice. The flow nozzle in each discharge line of the boiler feed pumps will operate the control valve in the recirculation line to maintain flow through the boiler feed pumps. The recirculation flow rate will be available to the operator through the Distributed Control and Information System (DCIS).

The major equipment in the Boiler Feedwater System will be the following:

- Three motor-driven boiler feed pumps
- Two or three high-pressure feedwater heaters.

Motor Driven Boiler Feed Pumps

Each of the three motor-driver boiler feed pumps will consist of a pump and an electric motor joined by hydraulic coupling. The motor-driven boiler boiler feed pumps will be the double case barrel, horizontal, seven-stage centrifugal, high-speed type. The capacity of the motor-driven boiler feed pumps will be controlled from minimum recirculation flow to maximum flow by adjusting the hydraulic coupling.

Each pump will have following approximate characteristic at 100% load:

- Capacity = 140 kg/s
- Total delivery head = 230 bars(g)

High Pressure Feedwater Heaters

High-Pressure feedwater shall be welded construction with stainless steel U-tubes. An integral desuperheating zone and drains sub-cooling zone will be provided with each high-pressure feedwater heater. The heaters have sufficient free surface area to provide stable level control.

3.3.16 Heat Rejection Systems

Circulating Water System

The Circulating Water System will supply brackish cooling water from Pakasai river to the condenser for condensing the low-pressure turbines exhuast steam. In addition, water for cooling will be supplied to the closed cycle cooling water heat exchangers. Stationary screens will strain the circulating water entering the circulating water pump suction pit. Water will be pumped through the condenser, the closed cycle cooling water heat exchanger, and the condenser exhauster seal water heat exchangers, then through the cooling tower and will be returned to the circulating water pump suction pit.

The major components of the Circulating Water System will be as follows:

- 2*50% Circulating Water Pumps
- One closed cycle cooling water circulating water pump
- One cooling tower

Circulating Water Pumps

The 2*50% capacity circulating water pumps will be the vertical, wet pit, mixed flow type. Both the pumps and the motors will be specifically designed for outdoor service. The bearing seal water will be provided from the service water system.

Closed Cycle Cooling Water Circulating Water Pump

The full capacity, closed cycle cooling water circulating water pump will be the vertical, mixed flow type. The pump will be designed for approximately 10 percent of the condenser water box flow and will be used to circulate water through the closed cycle cooling water heat exchangers when the plant is not in operation but closed cycle cooling is still desired, for example during startup and shutdown when cooling water will be needed for air compressors. A secondary function of this pump will be to prime the circulating water system before startup.

Cooling Tower

The cooling tower will be a mechanical draft counter flow wet-cooling tower system. Basic design data for cooling tower will be as follow (approximately):

- Heat Load	= 460 MW
- Inlet water temperature	= 43 degree C
- Outlet water temperature	= 32 degree C
- Evaporation loss	= 1.6 % CW flow rate
- Drift loss	= 0.002 % CW flow rate
- Cooling water flow rate	= 10 m^3/s

Closed Cycle Cooling Water System

The Closed Cycle Cooling Water System will transfer heat rejected by various plant equipment heat exchanges to Circulating Water System. The Closed Cycle Cooling Water System will supply condensate quality cooling water to plant equipment heat exchangers. The closed cycle cooling water heat exchangers, which are components of the Closed Cycle Cooling Water System, will transfer heat from the closed cycle cooling water to the circulating water. Three 50% capacity pumps will circulate the closed cycle cooling water through the cooling water heat exchangers and the various plant equipment heat exchangers. An elevated closed cycle cooling water head tank will provide surge capability, system makeup and venting and system static head.

To minimize corrosion, a corrosion inhibiting chemical solution will be added to the closed cycle cooling Water System through a chemical pot feeder. The various plant equipment heat exchangers will receive cooling water from a common supply header. The plant equipment heat exchangers will discharge the heated closed cycle cooling water to a common discharge header.

Normally, the individual equipment heat exchanger flow will be manually controlled by a balancing valve in the heat exchangers discharge piping. Independent control of the closed cycle cooling water supply will be required by plant equipment whose cooling requirements will be subject to appreciable change under varying plant operating conditions, and by equipment that requires precise temperature control.

The turbine lube oil coolers, generator hydrogen coolers, station air compressors, and control air compressors will be provided with independent controls. The air compressor cooling water will be returned to the closed cycle cooling water tank to allow for air venting if air-to-water side cooler leakage occurs.

The Closed Cycle Cooling Water System will supply plant equipment with cooling water at approximate 38 degree C. The equipment shall be supplied with closed cycle cooling water is as follow:

- Station Air Compressors
- Control Air Compressors
- Boiler Feed Pump Lube Oil Coolers
- Turbine Lube Oil Coolers
- Exciter Coolers
- Generator Hydrogen Coolers
- Sample Table Coolers
- Turbine Control Oil Coolers
- Hydrogen Seal Oil Coolers
- Induced Draft Fan Lube Oil Coolers
- Forced Draft Fan Lube Oil Coolers
- Air Heater Oil Coolers
- Gas Recirculation Fan Coolers
- Air Preheat Water Pumps
- High Pressure Heater Drains Pumps
- Boiler Feed Pump Lube Oil Coolers and Hydraulic Oil Coolers
- Low Pressure Heater Drains Pumps

- Condensate Pump Lube Oil Supply Units
- Boiler Circulating Water Pumps

The major components of the Closed Cycle Cooling Water System will be as follow:

- Closed cycle cooling water pumps
- Closed cycle cooling water storage tank
- Closed cycle cooling water heat exchangers

Closed Cycle Cooling Water Pumps

The pump will be the horizontal split case, single-stage, double suction volute type. The function of the closed cycle cooling water pumps will be to circulate closed cycle cooling water system through the Closed Cycle Cooling Water System at the desired flow rate.

Closed Cycle Cooling Water Storage Tank

The closed cycle cooling water storage tank will be the vertical cylinder, bottom supported type with provisions for connections and accessories designed for atmospheric pressure and a maximum temperature of 46 degree C. The closed cycle cooling water storage tank will have the following functions:

- Acts as a surge tank
- Provides net pump suction head for the closed cycle cooling water pumps
- Receives makeup water
- Serve as a means of venting the Closed Cycle Cooling Water System

Closed Cycle Cooling Water Heat Exchangers

Two 100% heat exchangers will be designed for circulating water on the tube side and closed cycle cooling water on the shell side. The heat exchangers will be single-pass, counter-flow type. The function of the heat exchangers will be to transfer heat from the closed cycle cooling water to the circulating water.

Condenser Cleaning System

The Condenser Cleaning System will use sponge rubber balls to continuously clean the tubes in the condensers and the closed cycle cooling water heat exchangers. The cleaning systems for the condensers and each closed cycle cooling water heat exchanger will separate. The cleaning systems will introduce sponge rubber balls through injection nozzles located on the circulating water inlet piping.

Four nozzles will be located on the circulating water piping to each low-pressure condenser inlet water box. One nozzle will be located on the circulating water piping to each closed cycle cooling water heat exchanger inlet. The balls, which are larger than the inside tube diameter, will be forced through the tubes by the differential pressure between the inlet and outlet. The contact pressure between the balls and the inside tube surfaces will remove accumulated deposits as the balls move through the tubes.

The balls will be removed from the circulating water by strainers located on the circulating water discharge piping. The ball will then be conveyed to the condenser cleaning pump suction. The condenser cleaning pumps will send the balls through collectors to the injection nozzles. Ball distributors will be located between the collectors and the injection nozzles for the cleaning systems servicing the two condensers. There will be no ball distributors required for two-closed cycle cooling water heat exchanger cleaning system. The pumps will develop sufficient head to overcome the pressure differential and the pressure losses in the ball transport piping.

The collector will be the point in the cleaning systems where the sponge rubber balls are added, checked for properly size, and retained during backwashing operations and cleaning system shutdown.

The major components of the Condenser Cleaning System will be as follows:

- Two condenser ball strainers
- Two condenser cleaning pumps
- One condenser ball collector
- One ball distributor
- Two closed cycle cooling water heat exchanger ball strainers
- Two closed cycle cooling water heat exchanger cleaning pumps
- Two closed cycle cooling water heat exchanger ball collectors

Condenser ball Strainers

The two-stage, included grid-type, vertical strainers will be located on each of the condenser outlet water boxes. The strainer sections will be rubber-lined carbon steel with stainless steel internals. The strainers will have motor-operated grid actuation.

Condenser Cleaning Pumps

The condenser cleaning pumps will be horizontal, bladeless pumps. The pumps will be of all stainless steel.

Condenser Ball Collectors

The collectors will be vertical, cylindrical basket-type collectors. The collectors will have rubber-lined carbon steel shells and stainless steel collector elements. Each collector will have vent and drain valves.

Ball Distributors

The distributors will be Y-type distributors with vanes and sight glasses. The distributors will have cast iron bodies and stainless steel vanes.

Closed Cycle Cooling Water Heat Exchanger Ball Strainers

One shell, one pass strainer will be located on each of the closed cycle cooling water heat exchanger circulating water outlets. The strainer sections will be rubber-lined carbon steel with stainless steel material. The strainers will have manually operated grid actuation.

Closed Cycle Cooling Water Heat Exchanger Cleaning Pumps

The recirculating pumps will be horizontal bladeless pumps. The pump will be of all stainless steel construction.

Closed Cycle Cooling Water Heat Exchanger Ball Collectors

The collectors will be vertical, cylindrical basket-type collectors. The collectors will have rubber-lined carbon steel shells and stainless steel collector elements. Each collector will have vent and drain valves.

3.3.17 Fuel Supply System

Fuel Oil System (Each Unit)

This system will supply No.6 (Heavy) fuel oil from the storage tank to the burners. The system will consist of fuel oil storage tank, fuel oil transfer pumps, fuel oil pumping units, fuel oil heating units, control valves, strainers and meters.

The fuel oil transfer pumps will take suction from the fuel oil tank. One of the two full capacity pumps will deliver oil through the fuel oil heaters to the burners. The tank will be equipped with level indications, alarm switches, and water draw-off connections.

The fuel oil transfer pumps will serve as a booster pumps on the fuel oil pump suction to provide proper net pump suction head. These pumps will be included in the event the fuel oil viscosity is greater than 3,200 centipoise (15,000 SSU), but they should not be needed under normal operating conditions. Each of these pumps will have a safety valve in the discharge to release excess pressure to the pump suction. Pressure in the fuel oil transfer pump discharge will be maintained by valves, which recirculate oil flow back to the storage tanks. Accumulators will be installed in the pump discharge to dampen pressure surges, which may occur when a pump is placed in service.

Fuel oil pump discharge pressure will be maintained by full capacity control valves, which recirculate excess flow to the storage tank. Accumulators will be provided in the fuel oil pump discharge header to reduce pressure surges induced when taking the burners in or out of service. Safety valves will be provided on the discharge of each pump in the event of control valve malfunction. Valves will be used to bypass the fuel oil pumps to permit recirculation around the pumps during initial startup and to allow a more gradual increase in velocity through the suction line. The duplex strainer in the pump suction line will require periodic cleaning when indicated by a high strainer differential pressure.

Oil leaving the fuel oil pumping unit will enter the fuel oil heater sets, each of which will contain a full capacity fuel oil heater. The heaters normally will use cold reheat steam to heat the oil; cold reheat will be backed up by the Auxiliary Steam System and deaerator extraction steam. Condensate from the fuel oil heaters will be drained to prevent possible contamination of the Condensate System. Fuel oil from the fuel oil heaters will be piped to the burners. The piping contains a safety shutoff valves, two parallel full capacity regulating valves, two minimum oil flow control valves, and two return oil flow meters. To aid unit startup, a recirculation valve will be provided just downstream of the fuel oil regulating station. This valve will be opened before light off of the boiler to permit hot oil flow through the control valves so that the valves can maintain the proper header pressure. The minimum flow regulators will maintain header pressure and will have a flow capacity sufficient to supply all burners at minimum burner pressure.

The main fuel oil header will be located above the top burner and the take off at boiler corners will be placed so that oil flows from the upper ring header down to the burners. This arrangement ensures that as the lower burners are fired, hot oil will flow in the header pass each of the upper burners during normal operation. Valve located at the lower end of each fuel oil supply header will provide a means of recirculating the hot oil through the headers before initial light off. Oil recirculated through these valves will be measured by fuel oil meters. A meter-operated valve can be operated from the control room to discontinue recirculation flow. The primary fuel oil flowmeters will measure the quantity of fuel to the burners at the outlet of the fuel oil headers. These meters will provide flow information to the Distributed Control and Information System and the Combustion Control System. The recirculation flow subtracted from the primary flow will determine actual quantities of oil burned.

The steam atomized oil guns will be provided. The lowest level will be capable of firing No.6 or No.2 fuel oil. The oil guns will be retractable and this function will be interlocked with the overall burner controls. Atomizing steam will be provided at a constant pressure. These will be burner shutoff valves, fire-safe ball valves that will be operated by a spring closing, air opening actuator.

A drain oil tank and drain oil pump will be provided to collect oil drainage from the fuel oil pumping unit, the fuel oil heating unit, and the ignitor oil pumping unit. Oil from the tank will be pumped by the drain oil pump back to the fuel oil return system. This pump will be a positive displacement pump.

Fuel Oil Pumps

Two full capacity positive displacement pumps will be provided. Each pump has a capacity 67 m^3/h and will be furnished as a complete unit with drive motors, duplex basket suction strainer, having 40 mesh screens, interconnecting pipe, valves, instruments and controls. Each pump will have a relief valve to protect it from over pressure.

Fuel Oil Heater

Two full capacity fuel oil heaters will be provided. The heaters will be the shell and tube type with the oil flowing through the tube side and steam on the shell side.

Accumulators

Accumulators will be bladder type pre-charged with nitrogen to dampen system pressure surges.

Fuel Storage Tank

The tank will be welded steel plate construction in accordance with API Standard 650 and will be complete with shell and roof manholes, external staircase, internal ladder, and water drain connections. The tank will serve one unit operating at 80% load for approximately 10 days. The tank has a capacity of 13,000 m^3.

Drain Oil Pump

The drain oil pump will be a positive displacement full capacity pump. It will be complete with motor, suction strainer, base-plate, and relief valve.

Ignitor Fuel System

The Ignitor Fuel System will supply No.2 (Distillate) oil to the steam generator Fuel Ignitor System. The system will utilize two ignitor oil pumps to dilivery oil from the ignitor oil tank (capacity of 500 m^3) to the ignitor oil cabinets at the burner elevations.

The system will also provide No.2 fuel oil to the warm-up buners, which will be the lowest level burner. Flow to the ignitors and warm-up burners will be regurated and metered. Accumulators will be provided in this system to reduce pressure surges when adding or removing burners or switching pumps.

The pump discharge pressure will be controlled through a control valve which maintains a suitable pressure in the ignitor oil header for the main flow control valve. The discharge line recirculates oil to the storage tank. Safety valves will be provided in the pump discharge to protect the systems in case the control valves malfunction. The station air will be used to atomize the oil at the ignitors. A control valve will regulate the air supply.

Ignitor Oil Pumps

The Ignitor Oil Pumps will be two full capacity positive displacement pumps. The pumps will be furnished as a unit with the drive motors, a duplex basket suction strainer having a 100-mesh element, safety valve, and interconnected piping, valves, instrumentation, and controls.

Accumulators

The accumulators will be the conical bag or bladder types, which are pressurized with nitrogen to resist, pressure surges in the line.

3.3.18 Water Supply and Treatment

Cooling Water System

The Cooling Water System will receive water from the Pakasai River. An intake structure will be located on the river. The water will flow into the intake structure through a traveling water screen dedicated to each of the two pump pits. Each pump pit will contain one full capacity raw water pump.

Service Water Treatment System

The service water system will provide potable quality water to the Cycle Makeup Treatment System, FGD system, building plumbing and sanitary systems, and general water use, including cleaning and flushing. The service water treatment system will receive water from the reservoir 1 & 2. The treatment will basically comprise filtration and solid reduction. The Service Water Treatment System will be a fully automated system comprising the following components:

- Two half-capacity carbon filters
- Two full capacity cartridge-type polishing filters
- Two full capacity, horizontal, centrifugal reverse osmosis feed pumps
- One rack-mounted reverse osmosis assembly
- Acid storage, solution, and feed equipment
- Scale inhibitor storage, solution, and feed equipment
- Sodium sulfite solution and feed equipment
- One reverse osmosis chemical cleaning skid
- One control panel complete with programmable controller
- One lot piping valves, instrument, and controls

The Service Water System will be designed to accommodate the peak service water demands of the plant site Service water will be supplied to the system by the service water pump taking suction from the service water storage tank. The service water treatment facility normally will supply water to the following equipment:

- Air Heater Wash Water System
- FGD system
- Fire water header
- Service water head tank
- Turbine lube oil centrifuge
- Vacuum priming air/water separators
- Circulating water pump motor bearing water storage tank
- Chimney hopper
- Safety showers and hose bibbs in the chemical feed area
- Hose bibbs in the turbine and boiler areas

The service water head tank, located on the boiler platform, will supply water in emergencies, maintain the head on the system, and vent entrained air. The major components of the Service Water System will be the service water head tank and the service water pump.

Cycle Makeup Treatment System

The Cycle Makeup Treatment System will provide high quality demineralized water for makeup to the steam cycle and closed cycle cooling system and for regeneration of the demineralizer and condensate polisher exchanger vessels.

The Cycle Makeup Treatment System will be a fully automated system designed for counterflow regeneration. The system will consist of the following components:

- One cartridge-type polishing filter
- Two cation exchanger vessels; one primary and one secondary, each containing strong acid resins.
- Two anion exchanger vessels; one primary and one secondary, each containing strong base resins.
- Two anion exchanger vessels; one primary and one secondary , each containing strong base resin
- One mixed bed exchanger containing strong acid, strong base, and inert resin
- Two full capacity, horizontal, centrifugal booster pumps
- Acid storage, dilution, and feed equipment
- Caustic storage, dilution, and feed equipment
- Sodium sulfite solution and feed equipment
- Two horizontal, electric, storage water heaters
- Two full capacity, horizontal, centrifugal regeneration water pumps
- One control panel complete with programmable controller
- One lot piping valves, instrument, and controls

The feedwater to the Cycle Makeup Treatment System will be pumped from the service water storage tank to and through the polishing filter. A sodium sulfite solution will be fed upsteam of the polishing filter to dechlorinate the service water. Free chlorine will damage the ion exchange resin and must be removed. Suspended solids larger than 5 microns will be filtered from the service water by the polishing filter. The polishing filter effluent will then pass through the primary pair of exchangers.

The primary exchanges will accomplish the majority of the ion exchange. The water will be progressively demineralized to the final desired quality in the secondary exchanger pair and the mixed bed exchanger. The effluent from the primary exchangers will flow to the demineralizer booster pump, where the water pressure will be increased to allow flow through the secondary and mixed bed exchangers. The effluent from the Cycle Makeup Treatment System will be directed to the demineralized water storage tank.

Condensate Polishing System

The Condensate Polishing System will maintain high quality water in the condensate feedwater system to help provide acceptable boiler water quality and steam purity. The system will provide both ion exchange for removal of dissolved solids as well as filtration of suspended solids from the condensate. The Condensate Polishing System protection of the steam cycle equipment during periods of condenser leakage and will allow continued thermal plant operation when there are leaks too small to locate but large enough to impact water quality present. The Condensate Polishing System will be a fully automated system consists of the following components:

- Three half-capacity deep bed polishing exchangers
- Four resin charges including strong acid, strong base, and inert resin
- One cation regeneration tank
- One anion regeneration tank
- One resin storage tank
- One resin hopper

- Two one-third capacity, horizontal, centrifugal recycle pumps
- Acid storage, dilution, and feed equipment
- Caustic storage, dilution, and feed equipment
- One horizontal, electric, storage water heater
- Two full capacity, horizontal, centrifugal regeneration water pumps
- One lime solution preparation system
- One control panel complete with programmable controller
- One lot piping, valves, instrument, and controls

The Condensate Polishing System will receive water from the discharge of the condensate pumps. The condensate will pass through exchanger beds consisting of a mixture of cation and anion resins with a small amount of inert resin. The effluent from the Condensate Polishing System will be returned to the Condensate System. When the ion exchanger capacity of the resin is exhausted or the pressure drop becomes excessive, thereby reducing the flow through any particular vessel, the standby vessel will be placed in service and the exhausted exchanger will be taken out of service. The resin from the exhausted exchanger will first be sluiced from the resin storage tank to the exchanger. The exchanger effluent will be recycled to the polishing system influent line by means of recycle pump following any exchanger outage, including resin transfer operations, prior to placing the exchanger in service or standby.

The exhausted resin will be hydraulically cleaned and separated in the cation regeneration tank. The inert resin will serve as an isolating zone between the cation and anion resins during the separation, thereby improving the separation and decreasing the possibility of improper regeneration of the resins. The anion resin will be hydraulically transferred to the anion regeneration tank. Sulfuric acid or hydrochloric acid will be used for regenerating the cation resin in the cation regeneration tank. Sodium hydroxide will be used for regenerating the anion resin in the anion regeneration tank. Dilute acid and caustic for regeneration of the cation exchangers will be provided by an in-line dilution system. The acid and caustic dilution water used in regeneration of the cation and anion resins will be heated to achieve a 32 degree C acid solution and a 49 degree C solution for improved ion elution from the resins.

Provisions will be made for the application of a dilute lime solution to the resin in the anion regeneration tank, following the caustic regenerant application. The dilute lime solution will elute sodium ions from any cation resin that carried over with the anion resin in the resin transfer. The dilute lime application step provides the capability to operate the condensate polisher past the point of ammonia break-through with a minimum of sodium throw. After regenerant application, the resins will be rinsed and then transferred to the resin storage tank. Here the resin will be mixed and stored until the cycle repeats.

3.3.19 Wastewater Collection and Treatment

Chemical Waste Collection and Treatment System

The Wastewater Collection and Treatment System will provide for the collection, treatment, storage and disposal of the plant wastewater. Inputs to the Wastewater Collection and Treatment System will be from the following sources.

- Cooling tower blowdown
- Floor and equipment drains from all buildings
- Steam generator blowdown
- Fuel oil unloading and storage areas
- Generator transformers area
- Auxiliary transformer area
- Neutralization basin effluent
- Sewage treatment plant effluent

The collected water from all the above sources, except the cooling tower blowdown and steam generator blowdown, will be routed through an oil separator. The discharge from the oil separator will be routed and discharged into the Pakasai River. The number and location of oil separators will be determined during detailed design and will as required for proper operation of the Waste Collection and Treatment System. The cooling tower blowdown will be routed to the seal well which will discharge at the outfall structure. The steam generator blowdown will be directly routed to the Pakasai River.

Sanitary Waste Collection and Treatment System

The Sanitary Waste Collection and Treatment System will collect the plant sanitary wastes, route the waste to a package sewage treatment system by means of gravity and pressure piping provide secondary treatment of the wastes, and discharge the treated effluent to the Wastewater Collection and Treatment System.

Sanitary wastes will flow by gravity to sanitary lift stations. The number and location of the lift station will be determined during detailed design. The waste collected in the sanitary lift station will be pumped to a lift station immediately adjacent to the sewage treatment plant that will serve as a surge tank and system feed point for the sewage treatment plant.

The sewage treatment plant will be an activated sludge unit using the extended aeration process method of treatment. A portion of the sludge will be recirculated in the treatment system unit complete digestion takes place. The process equipment will be contained within a below grade concrete basin with separate aeration and clarification sections. A comminutor will be used to reduce the size of the solids at the inlet to the plant. Chlorine contact chamber and chlorination systems disinfect the effluent before it is discharged to the Wastewater Collection and Treatment System.

3.3.20 Electrical System

Transformers

The unit generator will be connected to the 230 kV substation through a generator step-up transformer. It will be sized to match the rated generator output. The generator step-up transformer will be rated 212/283/353 MVA FOA/FOA/FOA. The primary (low-voltage) winding will connected to the generator with an isolated-phase bus duct, and the secondary (high-voltage) winding will be connected to the 230 kV substation with an overhead line.

One three-winding main auxiliary transformer for each unit will provide power to the plant switchgear buses: under normal operation, the main auxiliary transformer will carry the entire unit auxiliary load. It will be sized to supply the auxiliary load with 10 percent reserve capacity for future growth, The main auxiliary transformer primary winding will be rated 30/40 MVA OA/FA, and each secondary winding will be rated 15/20 MVA OA/FA.

The transformer will be delta connected on the primary winding and resistance-grounded wye on each 7,200 volts secondary winding. The transformer's primary winding will be connected to the isolated-phase bus duct between the generator and the generator step-up transformer with an isolated-phase bus duct tap; each secondary winding will be connected to one 6,900 volt switchgear lineup with a nonsegregated phase bus duct. Each secondary winding will have an on-load tap changer.

One two winding reserve auxiliary transformer, having a capacity of 30/40 MVA OA/FA, will supply the power to the 6,900 volt switchgear buses for unit startup. If the main auxiliary transformer is out of service, the reverse auxiliary transformer will carry the entire unit auxiliary load during plant operation. The reverse auxiliary transformer will be sized to supply the startup load of the unit and the entire unit auxiliary load at maximum generation, with 10 persent reserve capacity for future growth.

The transformer will be connected grounded-wye on the 230 kV primary winding and resistance-grounded wye on the 7,200 volt secondary winding. The primary winding of the transformer will be connected to 230kV substation with a overhead line. The secondary winding will be connected to one 6,900 volt switchgear lineup with nonsegregated phase bus duct. The primary winding of transformer will have an on-load tap changer.

The transformer sizing criteria for the station auxiliary transformers will be based on no reduction of generation or startup capacity with the loss of one of one main auxiliary or reverse auxiliary transformer.

6,900 Volt Switchgear

The switchgear will be designed for 7.2 kV continuous operation, the service voltage however will be 6.9 kV. Each 6,900 volt switchgear will power all motors rated 6,600 volts (typically motors rated 250kW and above) and all secondary unit substation transformer.

The 6.9 kV switchgear is metal clad type fully rated for the maximum expected short-circuit current and continuous current. All switchgear breakers are draw out type, electrically operated, stored energy vacuum circuit breaker type. Non-segregated phase bus duct is used for connections from unit auxiliary transformer and reverse auxiliary transformer to the 6.9 kV switchgear.

416 Volt Secondary Unit Substations

Secondary unit substation will be used to provide power to motor control centers and to medium sized, 380 volt motors (approximately 75 to 249 kW). Each transformer will be delta connected on the 6,900 volts primary winding and high-resistant ground-wye on the 416 volts secondary winding. The secondary unit substation main breakers, tie breakers, and motor feeder breakers will be electrically operated. The motor control center feeder breakers will be manually operated.

416 Volt Motor Control Centers

Motor control centers will be provided to feed all 416 volts loads not fed directly from a secondary unit substation. These loads include small 416 volts motor loads (less than 75 kW), power panel and lighting panel transformers, and all other miscellaneous 416 volts loads. Since the 416 volts system has a high-resistance grounded neutral, 416/240 volts panelboards will have to be fed through delta-wye transformer in order to have a solidly grounded neutral in the panelboard.

250 Volt DC System (Each unit)

The dc system will be rated 250 volts dc. The dc system will include the following equipment:

- One 250 volt dc station battery
- Two station battery fuses
- One 250 volt dc station battery panel
- Two station battery chargers
- Two 250 volt dc power panels

The two battery chargers will each be fully capacity, so that the system can operate normally with one changer out of service. The battery chargers will be designed for single and parallel operation with the associated battery. The parallel operation features of the battery chargers will include cross compensation, providing for equal sharing of the charger loads.

Changers will be designed for automatic load sharing during parallel operation. The dc loads will be fed from the power panels, with loads assigned to the two panels to provide maximum redundancy. The station battery panel will be connected to the continuous ac power equipment battery panel through two normally-open breakers; this tie will be used only in case of emergency. The dc panels will have fuses since the anticipated available fault current is greater than the interrupting capability of available circuit breakers.