# Main Electric Power and Balance of Plant Systems and Equipment of Qinshan Phas III CANDU Nuclear Power Plant

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**Abstract**
This paper provides a brief description of major systems for the Balance of Plant (BOP) and Electric Power distribution of QCNP. Electrical power systems deliver the useful product, electricity, to the grid. In addition these systems supply vital power to run the plant itself. Major BOP systems include thermal systems and equipment directly involved in converting energy in the steam into electrical power, the process service systems and equipment required to achieve proper performance of the conversion system, and the electrical power systems and equipment that supply the electrical energy to the various plant auxiliaries and also transport the electrical power to the grid.

## 1. INTRODUCTION

The efficiency of conversion of thermal power to electrical power in steam turbine generators is limited by the theoretical Rankine cycle efficiency and the efficiency of the prime mover (steam turbine generator) itself. The Rankine cycle efficiency does not presuppose the use of a turbine, an engine, or other prime mover and is a function purely of steam conditions. Thus for the given initial steam conditions and the pressure at which this steam will be exhausted, the Rankine cycle efficiency provides an indication of the theoretical maximum conversion of thermal power to electrical power. This theoretical maximum is further reduced by the efficiency of the prime mover, the steam turbine generator.

For the Candu-6 units the initial steam conditions of 680 psia of 99.75% saturated steam and exhausting at back pressure of 1.8 in. Hg provides a Rankine Cycle efficiency of approximately 39 %. This indicates that the 2063 MWth of the thermal power will result in a maximum possible electrical energy 804 Mwe. The efficiency of the turbine generator further reduces this energy.

Over the past few years, efforts have been made to improve the efficiency of the turbine generators. Generally the windage, friction and copper losses approximate to 3 %; thus the maximum possible efficiency of a turbine generator is 97 % referred to the Rankine cycle. Such a prime mover requires infinite stages of regenerative heating, and large turbine exhaust areas. Economics, however, indicate the laws of diminishing returns in the sense that higher efficiencies are achievable only at the expense of very high capital costs. Thus improvements in the turbine generator efficiency was mainly concentrated on a) finite number of regenerative feedwater heating stages, b) multistage reheating of steam after partial expansion through the turbine and c) increased exhaust areas. The regenerative feedwater heating where the feedwater is heated in stages is an attempt to make it follow the reversible process. The reheating of steam after it has partially expanded through the turbine is an attempt to increase the available energy. Higher turbine exhaust areas result in reduced exhaust losses and increased "used energy".

The current Candu-6 turbine generator utilizes six-stage regenerative feedwater heating, two stage steam reheating and large LP turbine exhaust areas (by using the largest proven size of last stage blades). The estimated efficiency of the current Candu-6 Turbine generator is 90.5% referred to the Rankine Cycle. A further 2.5% to 3% increase in efficiency is possible by using additional LP Turbines (Qinshan uses 2- LP turbines with 52-inch last stage blades. A 3$^{rd}$ LP turbine unit would increase output by an additional 20 MW approximately)

In the CANDU design the systems associated with the electrical power generation are termed as "Balance of Plant Systems"

The following provides a brief description of the systems for the Balance of Plant and the Electric Power distribution.

## 2. MAIN ELECTRIC POWER & BALANCE OF PLANT SYSTEMS & EQUIPMENT

The Main Electric Power and the Balance of plant systems and equipment essentially comprise the following:

- Thermal systems and equipment which are directly involved in converting the energy in the steam into electrical power,
- Process service systems and equipment required to achieve proper performance of the conversion system,
- Electrical power systems and equipment that supply the electrical energy to the various plant auxiliaries and also transport the electrical power to the grid

The following are the major thermal systems:

1. Main steam system which transports the steam from the Steam Generators in the Reactor Building to the Turbine Generators located in the Turbine Building.
2. Turbine Generator regenerative feed water heating systems comprising the extraction steam, the heater drains and vents systems
3. Condensing and Feed water system which condense the exhaust steam from the Turbine and transport the condensed water to the steam generators.

The following are the major process service systems:

1. Condenser cooling water
2. Service water (raw service water and re-circulated cooling water)
3. De-mineralized and domestic water
4. Instrument air

In addition to the above there are other systems for building services which comprise the Heating, ventilating and Air conditioning (HVAC), fire protection, drainage and service air.

The following are the major electrical power systems:

1. Class I system which supplies uninterruptible direct current (dc) to the essential auxiliaries
2. Class II system which supplies uninterruptible alternating current (ac) to the essential auxiliaries
3. Class III system which supplies alternating current (ac) to the essential users required for orderly safe shutdown of the reactor
4. Class IV system which supplies alternating current (ac) to all essential and non essential users
5. EPS (emergency power system) which supplies alternating current (ac) to some essential systems known as group 2 systems required for orderly shutdown of the reactor in the event of a seismic event

The following provides a brief description of the systems and components within the systems:

# 3. TURBINE GENERATOR AND AUXILIARIES

## 3.1 General

Each unit of the station has a turbine generator system that includes one turbine generator with associated condensing and feedwater systems. Each turbine generator is of the tandem compound reheat condensing type, with one double–flow, high–pressure section and two double–flow, low–pressure sections. Each turbine generator is a single shaft machine with a speed of 1500 rpm and a rated gross nominal output of 728 MWe.

The steam conditions at full load (rated continuous turbine capacity) are 4.51 MPa (absolute), 257.6°C at the high–pressure turbine throttle valves, with bleed steam and live steam reheat of the high-pressure turbine exhaust to 243.5°C.

The corresponding steam flows are:

- 3,568,074 kg/h to the turbine throttle valves,
- 150,726 kg/h live steam to the steam reheaters.

Major components of the simplified secondary cycle are shown in Figure 10.1-1. Heat balance diagram Figure 10.1–2 (a) indicates the more significant temperatures, pressures and flows within the cycle, at full power. The function of the turbine–generator is to convert thermal energy into electric power.

The turbine–generator is designed for the following conditions:

| | | |
|---|---|---|
| a. | Turbine–generator output, kW | 728,000 |
| b. | Throttle flow, kg/h | 3,568,074 |

| | | |
|---|---|---|
| c. | Steam conditions at throttle: | |
| | Pressure, MPa(a) | 4.51 |
| | Temperature, °C | 257.6 |
| | Moisture content, % | 0.3 |
| | Enthalpy, kJ/kg | 2792.6 |
| d. | Exhaust pressure, kPa(a) | 4.9 |
| e. | Stages of reheat | 2 |
| f. | Stages of feedwater heating | 6 |

The Hitachi, Ltd. turbine–generator is designated TC4F–52 and consists of a turbine, a generator, moisture separator–reheaters, exciter, controls, and auxiliary subsystems. The major design parameters of the turbine–generator are presented in Tables 10.2–1 and 10.2–2. Details of system components are also presented in this section.

## 3.2 Turbine–Generator Description

The turbine is a 1500 rpm, tandem–compound, four–flow, reheat unit with 52–inch last stage buckets. The turbine includes one double–flow high–pressure turbine, two double–flow low–pressure turbines, and two moisture separator–reheaters with two stages of reheating. The direct–driven generator is conductor cooled and rated at 817 MVA at 22 kV, 3–phase, 50 Hz. Other related system components include a complete turbine–generator bearing lubrication oil system, turbine control system, a turbine gland seal system, a turbine generator supervisory instrumentation (TGSI) system, overspeed protective devices, turning gear, a generator hydrogen and seal oil system, a stator cooling water system, an exciter cooler, a rectifier section, and a voltage adjuster.

## 3.3 Turbine–Generator Cycle Description

Steam from the main steam system enters the high–pressure turbine through four stop valves and four governing control valves. Cross–ties are provided both upstream and downstream of the stop valves to provide pressure equalization with one or more stop valves closed. A portion of the main steam is used for second–stage reheat of the steam supply to the low–pressure turbines. There are two steam extraction points in the high–pressure turbine. Steam from the first extraction point (high–pressure) is used for first–stage reheat of the two–stage reheater. Steam from the second extraction point is used for sixth–point feedwater heating.

After expansion in the high–pressure turbine, the steam flows through the moisture separator–reheaters to remove entrained moisture and to superheat the steam, thus improving cycle efficiency. A portion of the cold reheat steam is used for fifth–point feedwater heating. (Feedwater heaters are numbered sequentially in order of increasing extraction pressure.) Hot reheat steam is distributed equally to the two low–pressure turbines through combined intermediate stop and intercept valves. In each low–pressure turbine there are four steam extraction points, the highest-pressure extraction supplying the deaerator. The three other steam extraction points supply the remaining three stages of feedwater heating. After expansion in the low–pressure turbines, the steam is exhausted to the main condensers.

In addition to the external moisture separators, the last three low–pressure turbine stages are designed to remove any condensed moisture and drain it to the next lowest extraction. The moisture from the external moisture separators is drained to moisture separator drain tanks and from there to the fifth–point feedwater heater where it joins the heater drains cascading down to the deaerator. Similarly, the condensate from the first and second stage reheaters is drained to individual reheater drain tanks and from there to the sixth–point feedwater heaters. The condensate is flashed into the heaters for heat recovery after which the residual condensate joins the other heater drains cascading down to the deaerator.

### 3.4 Lubricating Oil System

The motor suction pump and turbine gear oil pump/jacking oil pump are used during the startup of the turbine generator unit. The emergency bearing oil pump is started when the pressure at the oil tank drops to an unacceptable value and/or ac power to the pump is lost, to permit a safe shutdown.

An oil purification system is connected to the turbine main oil tank and includes:

### 3.5 Generator

The generator is of the three-phase armature rotating field type. The field is four–pole. The stator windings are cooled by low conductivity water circulating through the tubular copper conductors around a closed circuit. The stator core is cooled by hydrogen gas flowing through radial ducts in the core, and the rotor winding by gas flowing in ducts in the copper conductors of the winding.

The excitation is of the static type, consisting of a solid-state automatic voltage regulator controlling a thyristor converter, which supplies the generator field via a dc bus duct and the generator slip rings and brush gear.

The main power output from the generator to the step–up transformer is by means of an air-cooled isolated phase bus duct, with tapoffs to the unit service transformer, excitation transformer and potential transformer cubicle.

The current transformers for metering and protection are installed on the main power output bushings of the generator.

### 3.6 Exhaust Hood Water Spray

During starting the turbine or while operating at no–load following loss of load, it is probable that the temperature of the steam from the reheater will be high enough to cause excessively high exhaust hood temperature. In order to avoid this undesirable condition, automatic desuperheating sprays have been provided in the low–pressure section of the turbine.

Guaranteed Parameters

| | Load |
|---|---|
| NSSS thermal output, MWt | 2063* |
| Steam generator outlet pressure, MPa(a) | 4.69 |
| Throttle pressure, MPa(a) | 4.51 |
| Throttle temperature, °C | 257.6 |
| Main steam flow, $10^6$kg/h | 3.57 |
| Gross electrical output, MWe | 728.0 |

Turbine–Generator Design Data

| | |
|---|---|
| Supplier | Hitachi |
| Unit designation | TC4F–52 |
| Last stage bucket length, cm | 132 |
| Design condenser backpressure (average for two shells), kPa(a) | 4.9 |
| Stages of reheating | 2 |
| Stages of feedwater heating | 6 |
| Rotational speed, rpm | 1500 |
| Guaranteed generator rating, MVA | 817 |
| Generator voltage, kV | 22 |
| Power factor | 0.9 |
| Short circuit ratio | 0.5 |

# 4. THERMAL SYSTEMS

## 4.1 MAIN STEAM SYSTEM

Steam generated in the four nuclear steam generators in the Reactor Building is supplied to the station turbine generator and the auxiliary steam systems at 4.69 mPa and 260 C. One pipeline per steam generator carries the steam to the main steam (balance) header located in the Turbine Building. Each pipe run incorporates the pressure safety, isolation and atmospheric steam discharge valves for the safety, isolation and pressure control of the secondary side of the steam generators. Steam supply to the turbine generator and the auxiliary systems is made from the main steam header. When the turbine trips, the steam is diverted from the same header and dumped into the condenser.

All main steam piping from the steam generators in the Reactor Building to the first anchor outside the R/B, including branch piping is classified as nuclear class 2. The rest of the system is classified as non-nuclear. Steam from the Main Steam Header is supplied to the following:

- High Pressure turbine, which includes four HP steam chests, emergency stop valve and governor valve
- Reheaters of exhaust steam from HP turbine exhaust
- Dump system to bypass steam to condensers during low load and load reject operations
- Deaerator for pegging during low load operations
- Seals of the turbine glands

Steam from the Header is fed to the HP turbine through emergency stop valves and governor valves. After expanding through the HP turbine, the steam is fed to two (2) moisture separator reheaters to remove the moisture and reheat the steam before being passed to the LP turbines. The reheated steam then expands down through the LP turbine sections and finally exhausts to the condenser where it is condensed.

Provisions are made to sample the steam and also to blanket the system with nitrogen during extended plant outages.

### 4.1.1 Main Steam Safety Valves (MSSVs)

A total of sixteen spring-loaded safety valves (four on each steam generator steam line) are provided. The safety valves have staggered set pressures and are designed to achieve full lift at 3% above their set pressures (accumulation).

An air-operated actuator is provided with each MSSV to enable remote control of the valve to open and depressurize the steam generator during Loss of Coolant Accident (LOCA) or loss of feedwater. A back-up instrument air tank for each MSSV is also provided to operate the MSSV's during loss of normal instrument air.

### 4.1.2 Atmospheric Steam Discharge Valves (ASDVs)

A total of four "globe" type control valves are provided (one for the steam main of each steam generator). These valves are used as a heat sink when the main condenser is either unavailable or is inadequate. The valves take care of minor pressure fluctuations during normal operation.

### 4.1.3 Main Steam Isolation Valves (MSIVs)

A total of four main steam isolation valves, one for each main steam line are provided. The main steam isolation valves are located downstream of the main steam safety valves and upstream of the atmospheric steam discharge valves.

The MSIVs would be operated only when there is a leakage from the steam generator tubes as detected by the tritium monitors in the feedwater, blowdown and main steam sampling lines in order to keep the radioactivity in the Primary Heat Transport System (PHTS) from being released continuously to the BOP side.

### 4.1.4 Condenser Steam Discharge Valves (CSDVs)

The main function of these valves is to discharge live steam from the main steam header to the condenser. They are used to discharge steam during severe transients, such as a turbine trip, to avoid activating the main steam safety valves.

The capacity of the condenser steam discharge valves (CSDVs) is equal to 100% of the maximum continuous rating (MCR) steam flow following a 100% load rejection.

## 4.2 STEAM GENERATOR BLOWDOWN SYSTEM

The evaporation of water in the steam generators produces an accumulation of the non-volatile impurities in the feedwater within the steam generators. To control this accumulation, the water containing the concentrated impurities is removed from selected areas of the steam generators by a process known as blowdown.

The heat from the blowdown water is recovered by flashing the high pressure and high temperature blowdown water from the steam generators in a blowdown tank. The resulting flashed steam from the blowdown tank is supplied to the deaerator. A substantial amount of heat energy is thus recovered from the blowdown water. The remaining water in the blowdown tank is discharged to the sea through the cooling water ducts after reducing its temperature to approximately 49 C.

## 4.3 CONDENSING SYSTEM

### 4.3.1 Main Condenser

The main condenser is the heat sink for the exhaust steam from the turbine generator and other cycle flows. During normal operation it receives and condenses the exhaust from the turbine generator. During abnormal operation it receives the bypass steam from the condenser steam discharge valves (turbine bypass). The main condenser also receives other miscellaneous steam cycle flows, drains and vents.

The main condenser serves as a heat sink in the initial phase of reactor cooldown during a normal plant shutdown.

The main condenser removes non-condensable gases from the condensing steam through the condenser air extraction system. It also provides for deaeration of the condensate such that the oxygen content does not exceed 10 ppb under any normal operating condition. This minimizes the occurrence of corrosion within the secondary system.

### 4.3.2 Condenser Air Extraction system

The main condenser air extraction system consisting of four vacuum pumps is designed to establish and maintain the shell–side vacuum by continuously removing non-condensable gases.

After the turbine seals are established, all four of the vacuum pumps may be operated initially to draw down air from the condenser and low–pressure turbine casings. During normal operation, two of the three 50 percent capacity vacuum pumps are operated to maintain the condenser vacuum at the design value. In the event of a partial loss of condenser vacuum, the standby pump also operates. A high condenser pressure alarm annunciates in the control room if the pressure reaches approximately 102 mm HgA. The turbine will trip if the main condenser air extraction system cannot maintain the condenser pressure below 178 mm HgA.

The condenser air extraction system is also designed to remove non-condensable gases any time the turbine bypass system is in operation. In the event the condenser air extraction system malfunctions and the condenser becomes unavailable, heat rejection from the steam generators is achieved by the atmospheric steam discharge valves (ASDVs) and the main steam safety valves (MSSVs).

## 4.4 REGENERATIVE FEEDWATER HEATING SYSTEM

### 4.4.1 General

The regenerative feedwater heating system provides for heating of the condensate to a suitable temperature before it is supplied to the steam generators. The system is comprised of the feedwater heating equipment, the extraction steam system, the feedwater heater drains system and the feedwater heater vents system.

The **extraction steam** system provides the required steam from the turbine extraction stages to heat the condensate flowing through the feedwater heaters. The final temperature of the feedwater leaving the last stage of the feedwater heaters is 187.0°C. The system is designed to limit the entrapped energy, protect the turbine from overspeed in the event of a turbine trip, and protect the turbine from water induction. All low points in the system between the turbine extraction stages and the check valves are provided with automatic drains to protect the turbine from water induction.

All **feedwater** heater drains systems are designed on the basis of preventing water induction into the turbine generators. The likelihood of encountering water hammer problems in this system between the high pressure heaters and condenser is reduced by selecting control valves that minimize cavitation and by increasing line sizes where two–phase flow is likely to occur.

All **feedwater** heater vents are designed to provide adequate venting of the feedwater heaters during startup and normal operation and to remove non-condensable gases to the condenser.

### 4.4.2 System Description

The feedwater heating system consists of the following items:

- Two parallel banks of three 65 percent capacity low pressure heaters through which the condensate is pumped to the deaerator, and two parallel banks of two 65 percent capacity high pressure heaters through which the feedwater from the deaerator is pumped to the steam generators
- Deaerator with integral vent condenser and a deaerator storage tank
- Extraction steam, heater drain and vent piping and valves
- Heater drain pumps, tanks
- Controls and instrumentation for extraction steam check valves, heater drain level control valves, etc.

The extraction steam piping is designed to preclude conditions that would promote turbine overspeed.

The feedwater heater drains system consists of two drain removal paths from each heater. The normal drain flow path is cascaded to the next lower stage heater and the alternate (emergency) path is diverted to the condenser. The drain systems are sized for handling abnormal flow increases due to single bank operation and are designed to avoid water/steam hammer problems.

The feedwater heater vent system removes non-condensable gas from the heater shell and drain cooler spaces and assures proper heat transfer. The vent lines are sized to handle abnormal flows during startup.

## 4.5 CONDENSATE AND FEEDWATER SYSTEM

The condensate and feedwater system provides heated feedwater to the steam generators. The condensate system provides condensate from the condenser hotwell to the deaerator. The feedwater system provides feedwater from the deaerator to the steam generators.

The condensate and feedwater system includes:

- Main and auxiliary condensate extraction pumps
- Regenerative feedwater heater, deaerator and deaerator storage tank
- Main and auxiliary steam generator feedwater pumps

- Reserve feedwater storage tank
- Piping and valves for the complete system.

There are two 100 percent capacity main condensate extraction pumps and three 50 percent capacity main steam generator feedwater pumps.

Two high-pressure feedwater heating stages with incorporated drain cooling sections, a deaerator and three low-pressure feedwater heating stages, with incorporated drain cooling sections, are provided in the feedwater system. Each closed heater stage is divided into two heaters so that two independent regenerative lines are provided.
The heaters with integral drain coolers are of the horizontally arranged type, with U–tubes, located on either side of the turbine block. Heater No. 4 (deaerator) is a horizontal, direct contact, tray–type deaerating feedwater heater, with storage tank.

The condensed extraction steam cascades from one heater shell to the next lower pressure heater shell, where additional heat is transferred to the steam generator feedwater. The low-pressure heater drains cascade back to the condenser hotwell. The high-pressure heater drains cascade back to the deaerator storage tank

Feedwater is pumped to the steam generators in the reactor building by means of the main steam generator feedwater pumps. The normal operating temperature of the feedwater at the exit of the final (No. 6) feedwater heater is 187.0°C.

An auxiliary steam generator feedwater pump (on Class III power) is fed from the deaerator storage tank. An auxiliary condensate extraction pump (on Class III power) replenishes the deaerator and takes suction from the condenser hotwells, which are in turn replenished from the reserve feedwater storage tank, and this in turn is replenished with water from the demineralized water storage tanks.

The feedwater system downstream of the deaerator (including the deaerator) has the capability of maintaining the proper feedwater inventory in the steam generator during startup and normal operation.

The chemistry of the feedwater entering the steam generators is controlled to protect against chemical damage of the steam generator tubes.

## 4.6 CONDENSATE MAKE-UP AND REJECT SYSTEM

The condensate make–up and reject system serves to receive the excess condensate and/or to supply the condenser with make–up water during normal and abnormal plant operations.

## 4.7 MOISTURE SEPARATOR/REHEATER DRAINS SYSTEM

The steam condensed in the moisture separators/reheaters of the turbine generator is drained to the high-pressure heaters.

## 4.8 AUXILIARY SYSTEMS

In addition to the major systems and equipment described on the preceding sections, the following auxiliary systems are also provided:

The more important accessories are

- Sampling system, which permits condensate and feedwater samples to be taken for chemical analysis
- Steam drain system, which recovers heat and treated water (condensate) from the various equipment drains
- Chemical injection system, which is used to add chemicals to the condensate and feedwater systems to maintain and control the chemistry within the specified ranges.

# 5 SERVICE SYSTEMS

## 5.1 Condenser Cooling Water System

The system supplies the cooling water required by the steam turbine condenser. The cooling medium is seawater.

Two 50 percent capacity circulating water pumps are located in the pumphouse for each unit, each pump having independent suction from the pumphouse forebay. The pumps will operate normally in parallel, but continuous smooth unit operation is possible with one pump, at a discharge rate which exceeds 60 percent of the total rated discharge for two pumps. The circulating water is distributed to the condenser shells and then discharged into the outfall. Each pump discharge and the inlets and outlets of the condenser water boxes are provided with motorized butterfly valves.

The cooling water is seawater and the condenser temperature rise is restricted to a maximum of 9.5°C under normal operating conditions. The condenser circulating water is strained of small debris and fish that pass through the trash racks by self–cleaning, dual–flow travelling screens. A continuous, on–line sponge–ball condenser tube cleaning system is incorporated to minimize condenser tube fouling.

## 5.2 Service Water Systems

### 5.2.1 General

The systems utilizing sea water required for each station include a condenser circulating water system as described above, a raw service water system, and a screen wash system.

Recirculated cooling water, fire protection, domestic water, demineralized water and emergency water supply systems are supplied from fresh water sources. Other water systems include the drainage and chlorination systems.

Service Water Systems

The service water systems include:
- The raw service water system (RSW)
- The recirculated cooling water system (RCW)

The raw service water (RSW) system and the recirculated cooling water (RCW) system provide the heat sink when Class III and Class IV power is available. The main cooling medium is seawater. The raw service water system supplies seawater to the recirculated cooling water system heat exchangers. The recirculated cooling water system is a closed loop of treated water that supplies cooling to turbine hall auxiliaries and certain NSP loads. Thus RCW/RSW heat exchangers remove all the heat loads that are ultimately rejected to the seawater. The service water systems provide cooling water to non–safety related systems to support unit power generation, and safety related systems to mitigate the effects of accident conditions. The individual flow requirements for these systems and the RCW system heat loads under normal and abnormal operating conditions with Class IV or III electric power, supplies available form the basis for the service water systems design.

The RCW design supply temperature to reactor building users is 35°C. During the summer, the RCW system temperature may be as high as 36.7°C during normal operation.
The service water systems are not required to be functional during and after a seismic event.

### 5.2.2 Raw Service Water System

Each of the unit's raw service water systems supplies sea water to the turbine hall auxiliaries that are designed for cooling with sea water and to the recirculated cooling water system heat exchangers located in the turbine building.

The RSW design supply temperature will be 30.5°C. During summer periods, a temperature of 32°C may be experienced. The water temperature limits noted below will not be exceeded.

| RSW TEMP | RCW Cold Side Temp | RCW Supply Temp |
|---|---|---|
| 30.5°C | 35°C | 35°C |
| 32°C | 36.7°C | 36.7°C |

The raw service water is supplied by four (4) 33–1/3 percent capacity pumps, located in each of the pumphouses. The pump housings are NI–Resist iron with stainless steel impellers, and stainless steel shafts, fitted with stainless steel sleeves. The pumps are normally supplied with Class IV power. On loss of the Class IV power, one pump operates on each energized Class III bus. The pumps discharge into a manifold, and from there into three (3) 50% capacity self–cleaning strainers. The strainers remove all particles larger than 3 mm, are automatically back washed as pressure drop increases and provided with isolation and bypass valves.

### 5.2.3 Recirculated Cooling Water System

Each of the two unit's recirculated cooling water system is a closed loop of treated water supplying cooling to all equipment for which salt water is unsuitable. The system operates at 691 kPa(g) (100 psig) at the pump discharge header. The pressurization system consists of an expansion tank (head tank vented to atmosphere) connected to the suction side of the RCW pumps. The recirculated cooling water is cooled by four 33–1/3 percent counterflow heat exchangers arranged in parallel.

Three of the four RCW heat exchangers are operating and one is on standby. During the period of higher RSW temperatures, the fourth heat exchanger could be brought on line to provide additional cooling. The fluid in the RCW system will be treated to provide a corrosion inhibiting film on carbon steel surfaces and maintain the pH within acceptable limits. Treatment includes a 5µm filter installed in a RCW pump bypass.

The make–up to the RCW system is demineralized water. The tube side contains sea water. A sponge ball cleaning system mitigates heat exchanger tubeside fouling. Flow in the recirculated cooling water system is provided by four (4) double volute, double suction, horizontal pumps each rated at 33–1/3 percent of total required flow. The pumps have carbon steel casings and stainless steel impellers.

The pumps are normally supplied with Class IV power. Following loss of Class IV power one pump operates on each energized Class III bus. One RCW pump can satisfy the flow requirements in case of Class IV power loss.

Makeup to the RCW system is provided to the RCW head tank. Flow from the RCW head tank into the RCW system is measured and alarmed by a flow element. This will alert the control room to leakage and provide a direct measure of the leakage from the RCW system.

### 5.2.4 Demineralized Water System

The water treatment plant is designed to provide enough capacity for both units.

The demineralized water is used to meet nuclear steam plant requirements, for the make–up to the condenser hot wells, for steam generator blowdown and to provide for the other miscellaneous uses.

The water treatment plant is in two sections, a pre–treatment section and a demineralizing section. The pre–treatment plant produces water for the demineralizing section and also for domestic water supply. The capacity of the pre–treatment section is 92.1 L/s (1400 GPM).

The demineralization plant has a capacity of 34.7 L/s (550 GPM) demineralized water and it includes multi–train Reverse Osmosis (R/O) and demineralization systems and all required regeneration equipment.

The dimineralized water quality is:

| | |
|---|---|
| Sodium | □ 0.03 parts per million (ppm) as $CaCO_3$ |
| Chlorides | □ 0.03 ppm as $CaCO_3$ |
| Silica | □ 0.02 ppm as $SiO_2$ |
| Conductivity | □ 0.2 micro–mhos/cm |
| pH | 6.0 to 7.5 |

### 5.2.5 Domestic Water System

The system is shared between two units but has a dedicated distribution system and emergency shower tank for each unit. Domestic water is supplied to the system from the site domestic water supply.

The domestic water system is sized to provide sufficient capacity to support the cold and hot water system needs of 2400 people and for the supply to the station demineralized water system.

### 5.2.6 Chilled Water System

The chilled water system is a closed loop system that supplies chilled water to the various ventilation and air conditioning systems in the plant, to the local air coolers for safety and non–safety related services in the reactor and service buildings, and to the coolers for $D_2O$ vapour recovery system.

The system is designed to provide chilled water to various users at a temperature of approximately 6°C (43°F). The chillers are cooled by one of the service water systems.

The chilled water systems of the units are independent identical systems. The principle equipment for each system is located in the respective turbine building. The system comprises three 50% capacity chillers, two expansion tanks and two (2) chilled water, recirculating water pumps. The approximate flow rate of each pump is 240 L/s at 122 kPa.

There are three (3) chilled water distribution circuits in each unit. Each circuit is equipped with two (2) 100% capacity pumps. The chilled water system is chemically treated to inhibit corrosion.

## 5.3 COMPRESSED-AIR SYSTEMS

The compressed air is supplied to three systems.

- Two 100% duty oil–free compressors supply the instrument air requirements of each unit.
- One 100% duty, oil–free compressor supplies the breathing air requirements of both units.
- Service air requirements of both units are supplied by two 100% duty, compressors located in Unit 1.

The compressors and associated equipment for the shared service and breathing air compressors are located in the Unit 1 turbine building of each unit. The instrument air compressors are located in the turbine building of each unit.

Mask air is fed locally from the breathing air compressor outlet header, with adequate pressure reducing equipment to provide an acceptable supply at the mask air stations. The breathing air compressor is connected to Class III power supply to ensure availability during loss of Class IV power.

Instrument air is dried in a dual dessicant type dryer before it is delivered. Standby power supply (Class III) to the instrument air compressors ensures an instrument air supply for essential services in the event of main plant power (Class IV) failure. To cover the unlikely event of complete failure of the instrument air supply, there is sufficient air receiver capacity, augmented by local air tanks/bottles to enable the operator to shut down the station safely.

# 6 ELECTRICAL POWER SYSTEMS

## 6.1 General

The electrical power supply and distribution system within the plant consists of four (4) classes of normal power supplies and an Emergency Power Supply (EPS) system. The four classes of the normal power supply are considered as part the Balance of Plant design.

The power from the Generators is supplied to the grid via the 220 kV and 500 kV systems. Each unit is provided with a Unit Service Transformer (UST) and a Station Service Transformer (SST). These two service transformers supply the entire station service load.

The distribution systems for all classes of power at all voltage levels are divided into odd and even buses so that dual bus, or better, reliability is provided. This odd/even bus concept is applied to equipment, raceway system, junction boxes etc., in order to maintain physical separation between odd/even systems to achieve maximum reliability under normal and abnormal conditions.

## 6.2 Main power output system

The main power output system transmits the power produced from the generator terminals via the main generator breaker and the isolated phase bus duct to the main output transformer. It also supplies the unit service transformer and the 22 kV potential transformers

The main output transformer is a 3-single phase step-up transformer rated at 3 x 277 MVA and steps up the generator voltage from 22 kV to 500 kV

## 6.3 Power Supply and distribution System to station services

The four classes of power distribution systems are:

- Class I system that supplies uninterruptible direct current (dc) to the essential auxiliaries. For control, protection and safety equipment. The voltage levels are 48 V dc, 220 V dc and 400 V dc.
- Class II system which supplies uninterruptible alternating current (ac) to essential auxiliaries, control and protection equipment. The voltage levels are 380 V ac, 3-phase 50Hz ; 208 V ac, 3-phase 50 HZ; 380/220 V ac 3-phase, 4 wire 50 Hz for emergency lighting/ building services and 120 V ac single phase 50 Hz
- Class III alternating current (ac) supply to essential auxiliaries that can tolerate a short duration of power outage. These essential auxiliaries are necessary for the orderly safe shut down of the reactor and turbine. The voltage levels are 6000 V ac, 3-phase, 4-wire 50 Hz; 380 V ac, 3-phase 50 Hz; and 380/220 V ac 3-phase 4-wire 50 Hz for lighting/building services
- Class IV alternating current (ac), the normal supply to the auxiliaries and equipment that can tolerate long duration of power interruptions without affecting the plant safety. The voltage levels are 11,000 V ac, 3-phase, 50 Hz; 6000 V ac, 3-phase, 4-wire 50 Hz; 380 V ac, 3-phase 50 Hz; and 380/220 V ac 3-phase 4-wire 50 Hz for lighting/building services and 208/120 V ac, 3-phase, 4 wire, 50 Hz.

The 11.6 kV system consists of two class IV buses, one “odd” and one “Even”. The voltage level of 11.6 kV is obtained from the secondary windings of the system service and unit service transformers. The 6.3 kV system likewise consists of two class IV buses, one "odd" and one "Even" supplied from the secondary windings of four 11.6 kV-6.3 kV dry type air cooled step-down transformers.

The station 400 V class IV supply system is fed from a 11.6 kV-400 V dry type transformer. Likewise the 400 V class III system is fed from the 6.3 kV class III by four transformers.

There are two 400 V 3-phase class II buses. They derive their supply normally through inverters, which in turn is from a rectifier in parallel with a 400 V battery. The rectifier is supplied from class III. On a loss of Class III, the batteries provide continuous supply to the class II through the inverters. On the loss of an inverter, the alternative supply is provided from the associated class III bus. These buses feed the class II critical motor loads and the 380 V/220 V, 3-phase, 4-wire emergency lighting system.

Three 120 V single phase buses are fed through inverters from the 220 V batteries in parallel with a rectifier that is supplied from Class III. In the event of a class III power failure, the inverter continues to be supplied from the battery without interruption. These buses supply the ac instrumentation loads and the station control computers.

The class I dc supply consists of ungrounded 48 V dc and 220 V dc. The 48 V dc comes from three independent batteries. Each provides power for control logic circuits and safety systems. The three batteries allow for each channel of a triplicated reactor safety circuits to be supplied independently. Similarly there are three 220 V batteries. These provide power for dc motors, switchgear operation and for the 120 V, 1 -phase, class II ac through inverters. Both the 48 V dc and 220 V dc batteries are rated for sixty minutes.

A standby AC power system is also provided for the Class III loads by two diesel engine driven sets. These are standby diesel generators housed in two separate rooms. Each diesel generator is sized to supply the total safety shutdown load of the unit. In the event of failure of the station class IV load the two standby diesel generators will start automatically

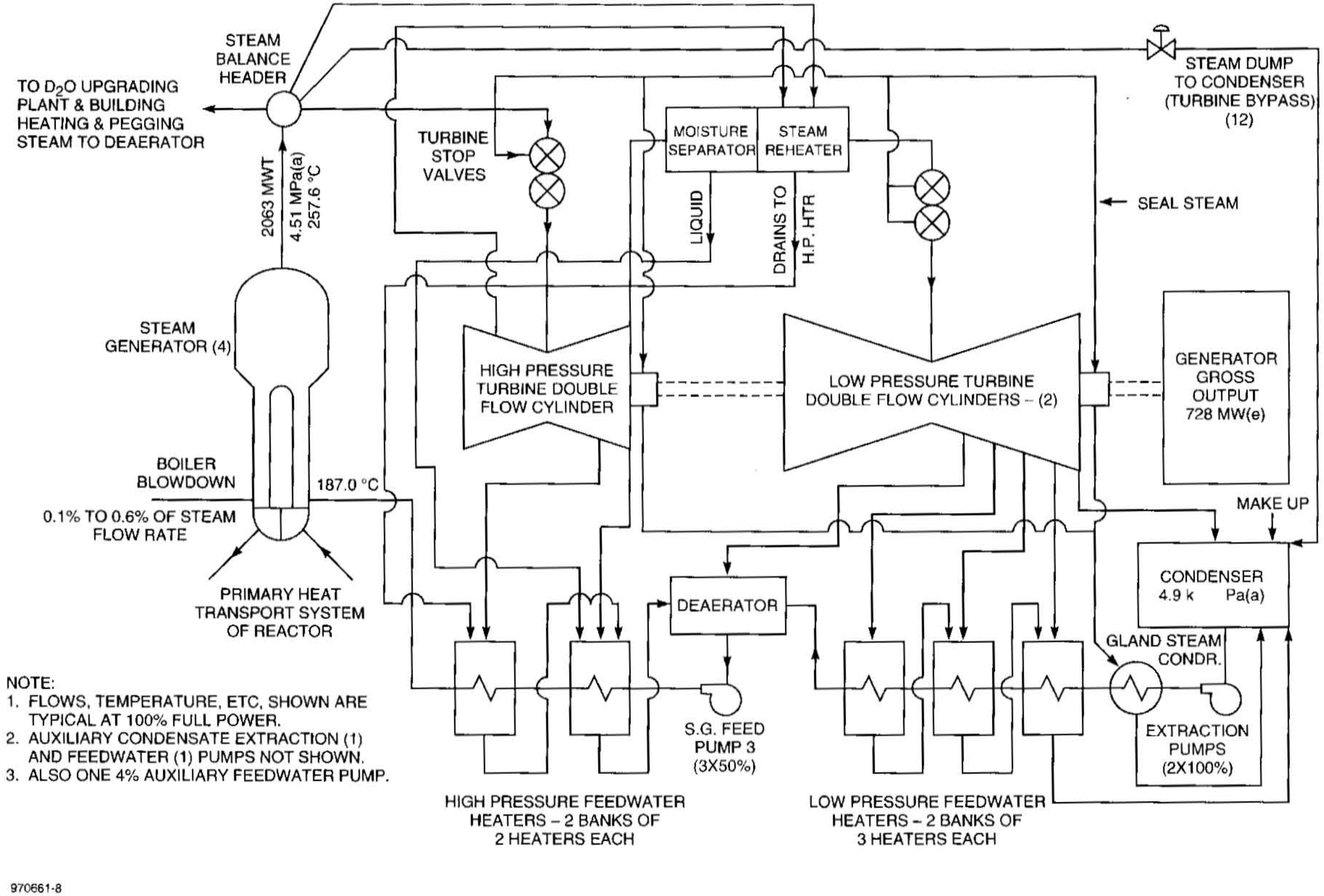


**Figure 10.1-1 Simplified Turbine and Feedwater Arrangement**

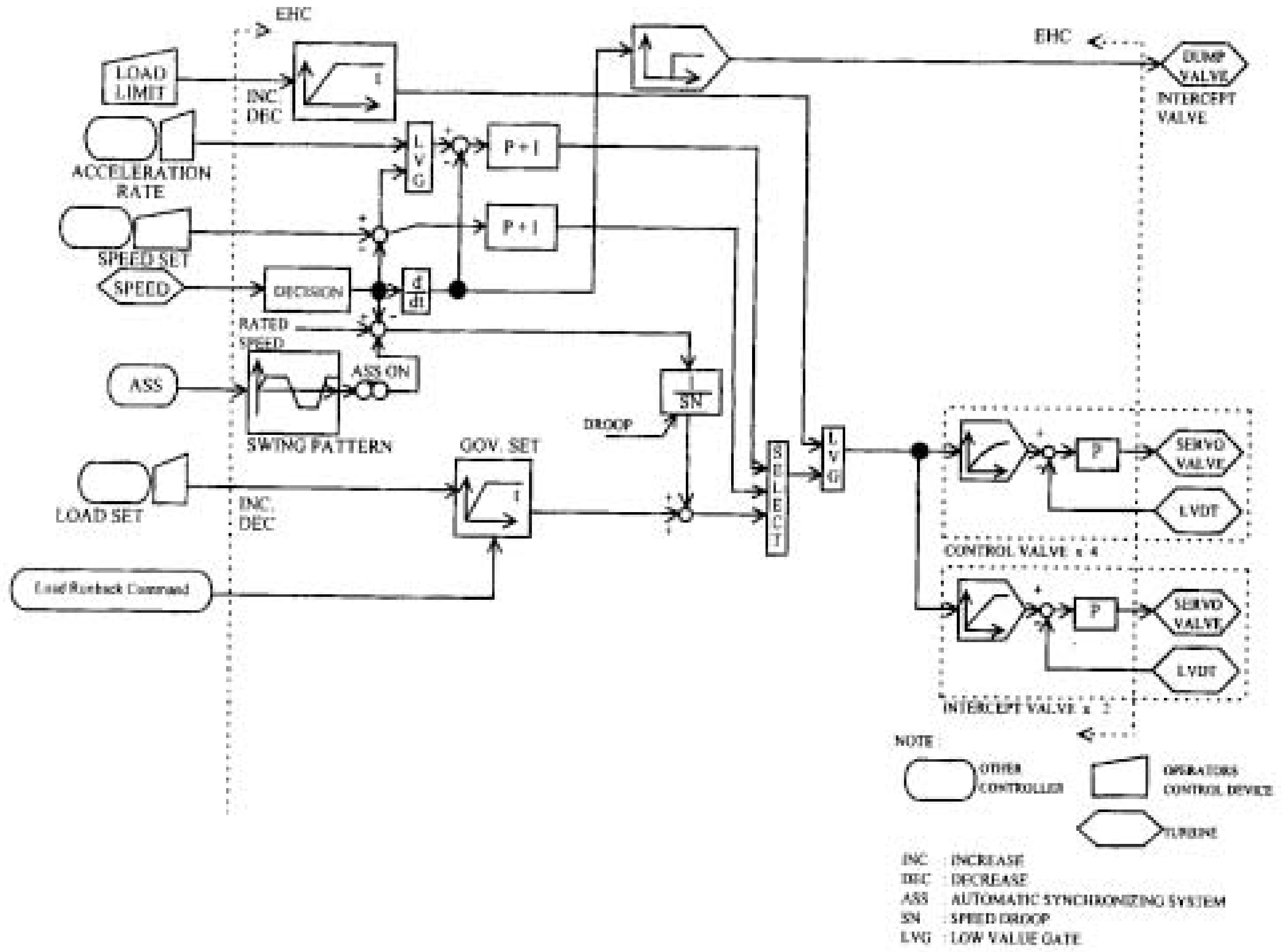


**Figure 10.2-1 Control Block Diagram of EHC System**

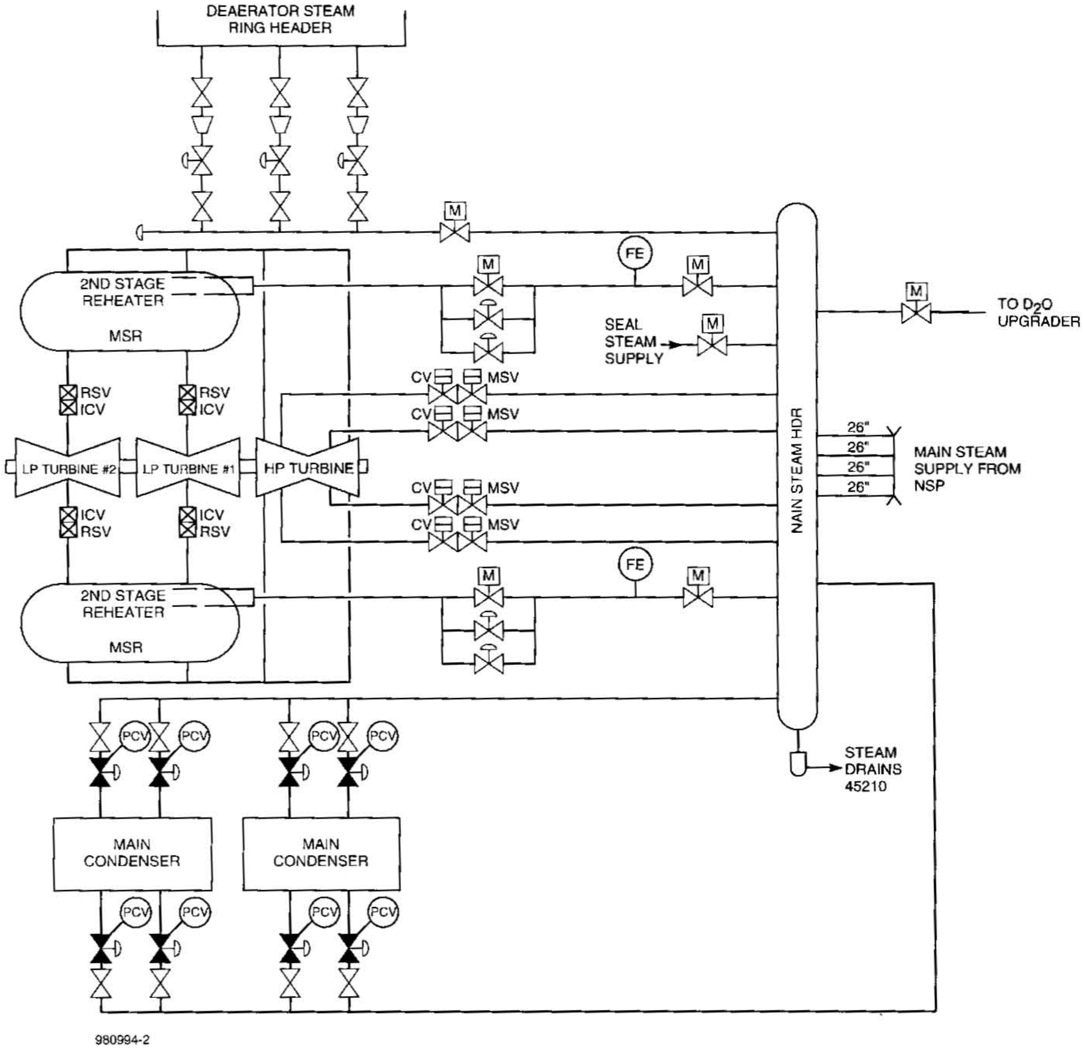


**Figure 10.3-1 Main Steam, Auxiliary Steam and Turbine Bypass Systems**

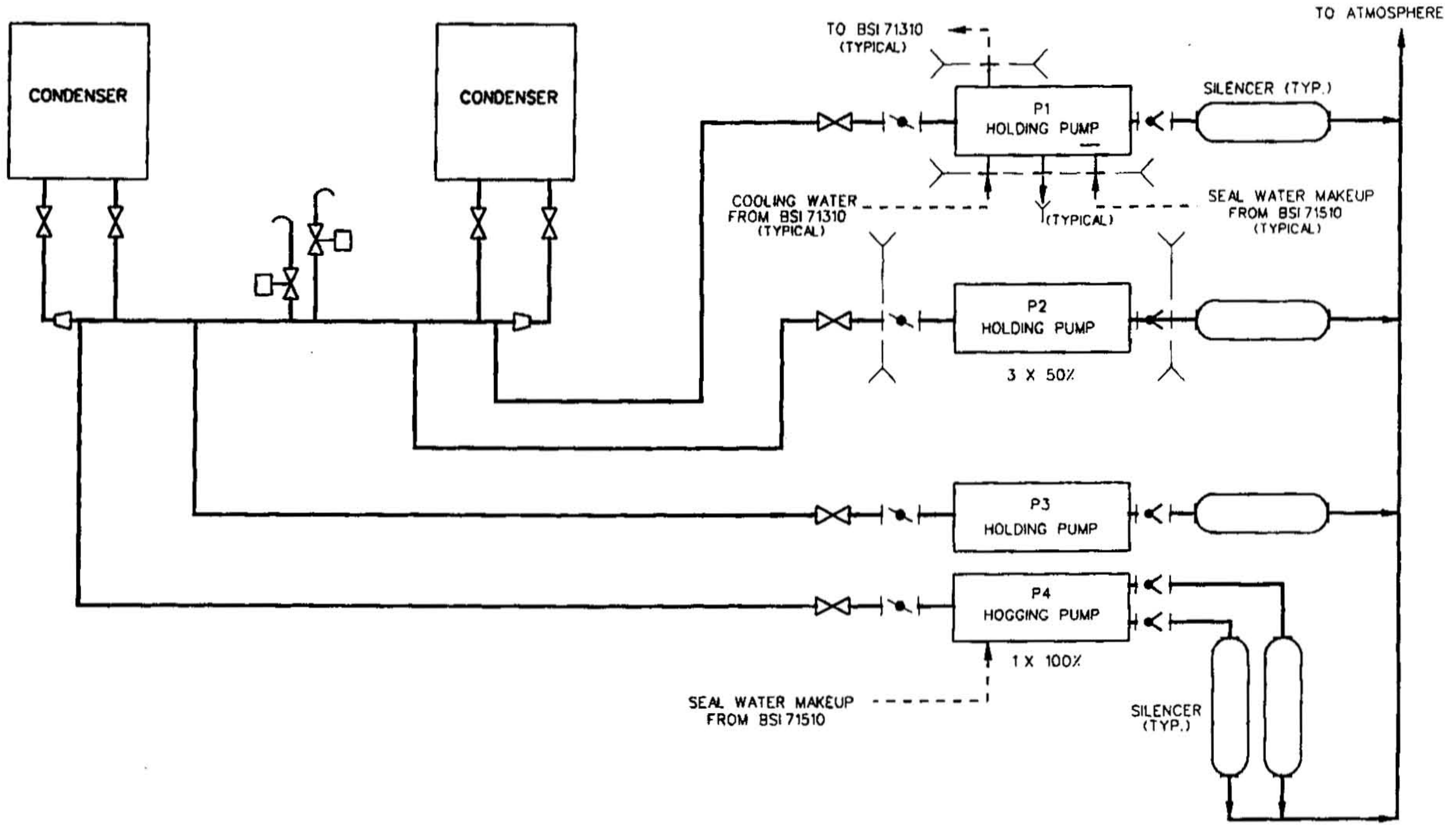


**Figure 10.4-1 Condenser and Auxiliaries Flowsheet**

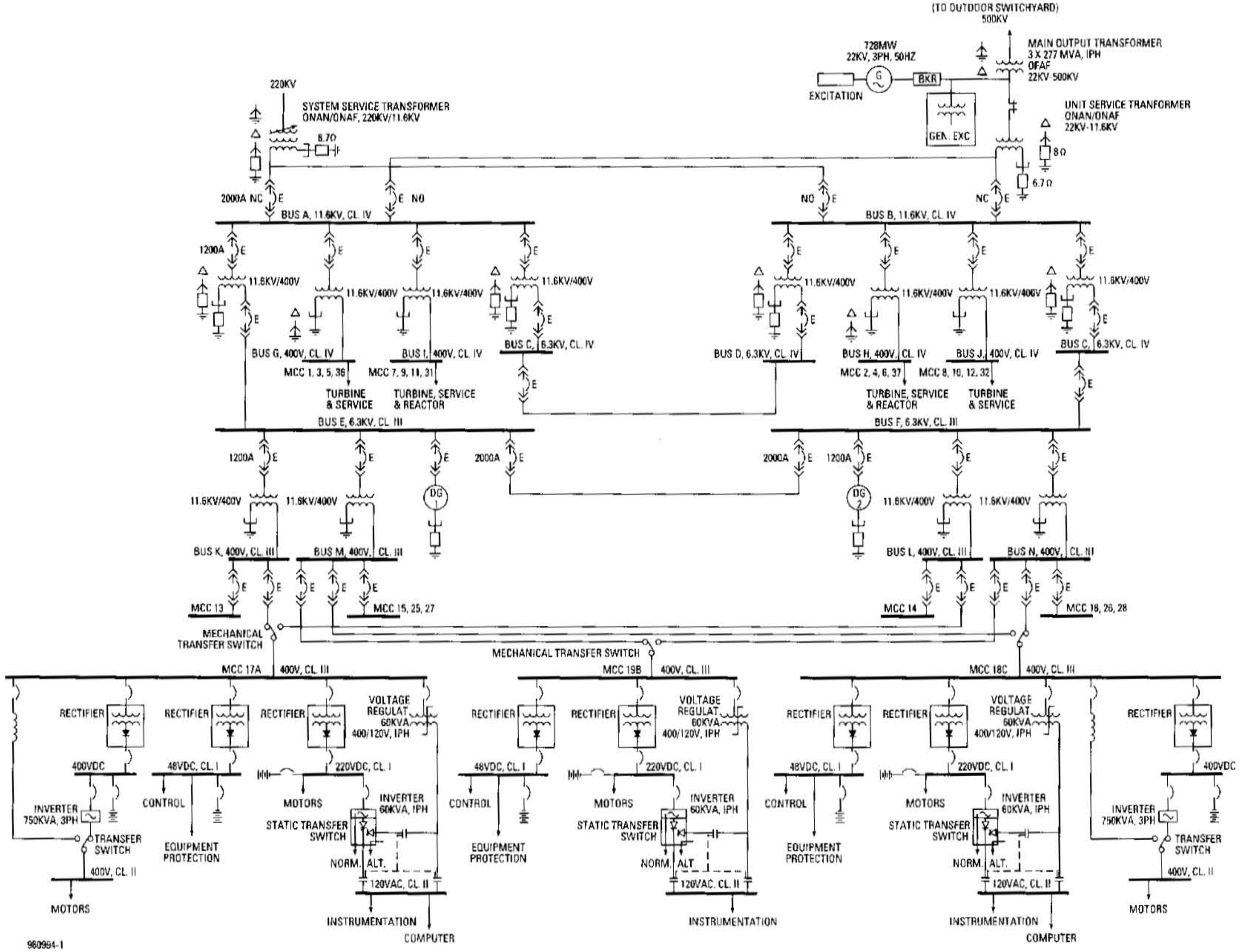


**Figure 10.5-1a High Pressure Extraction Steam System and Heater Drains**

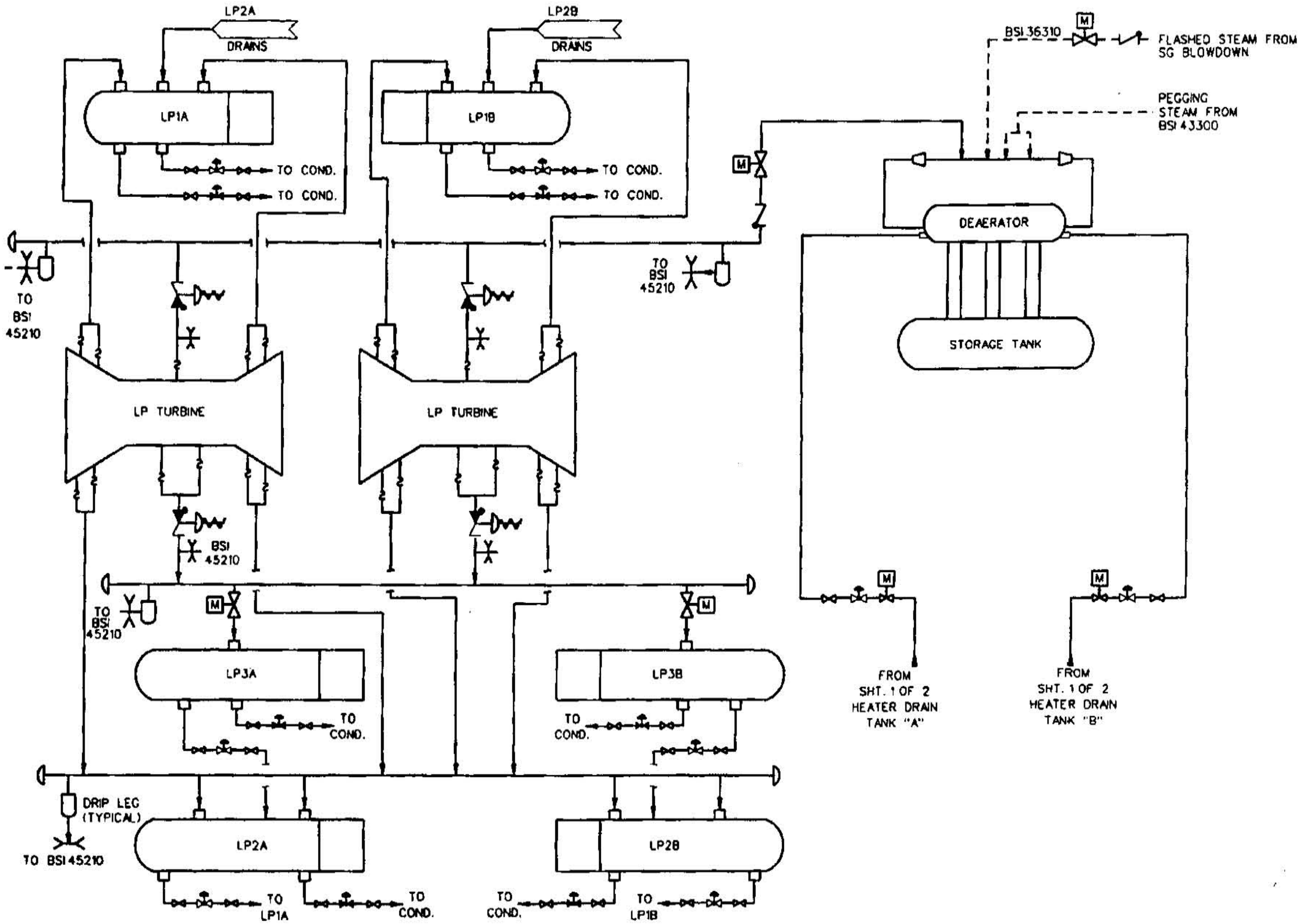


**Figure 10.5-1b Low Pressure Extraction Steam System and Heater Drains**

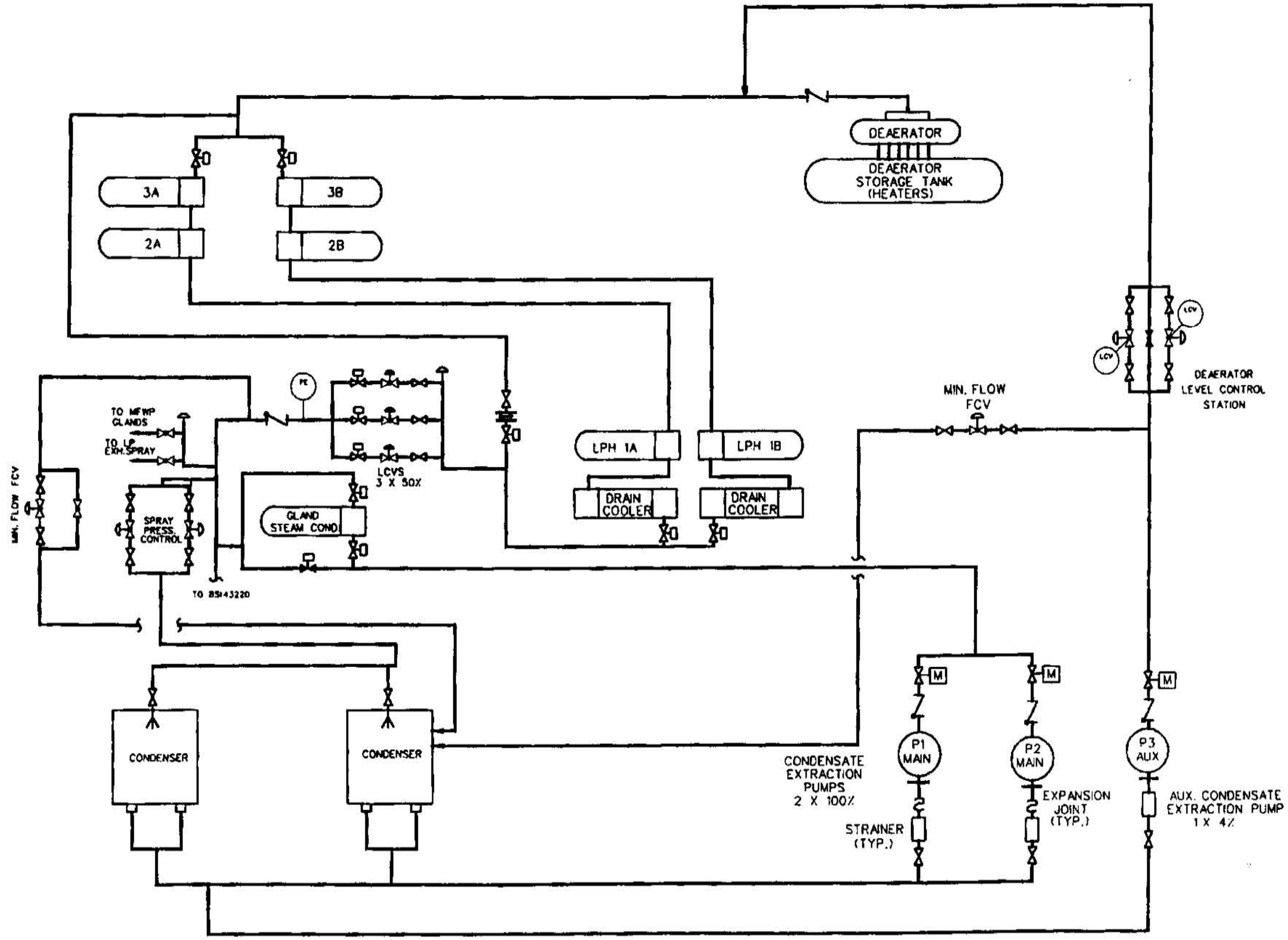


Figure 10.5-2a Condensate System

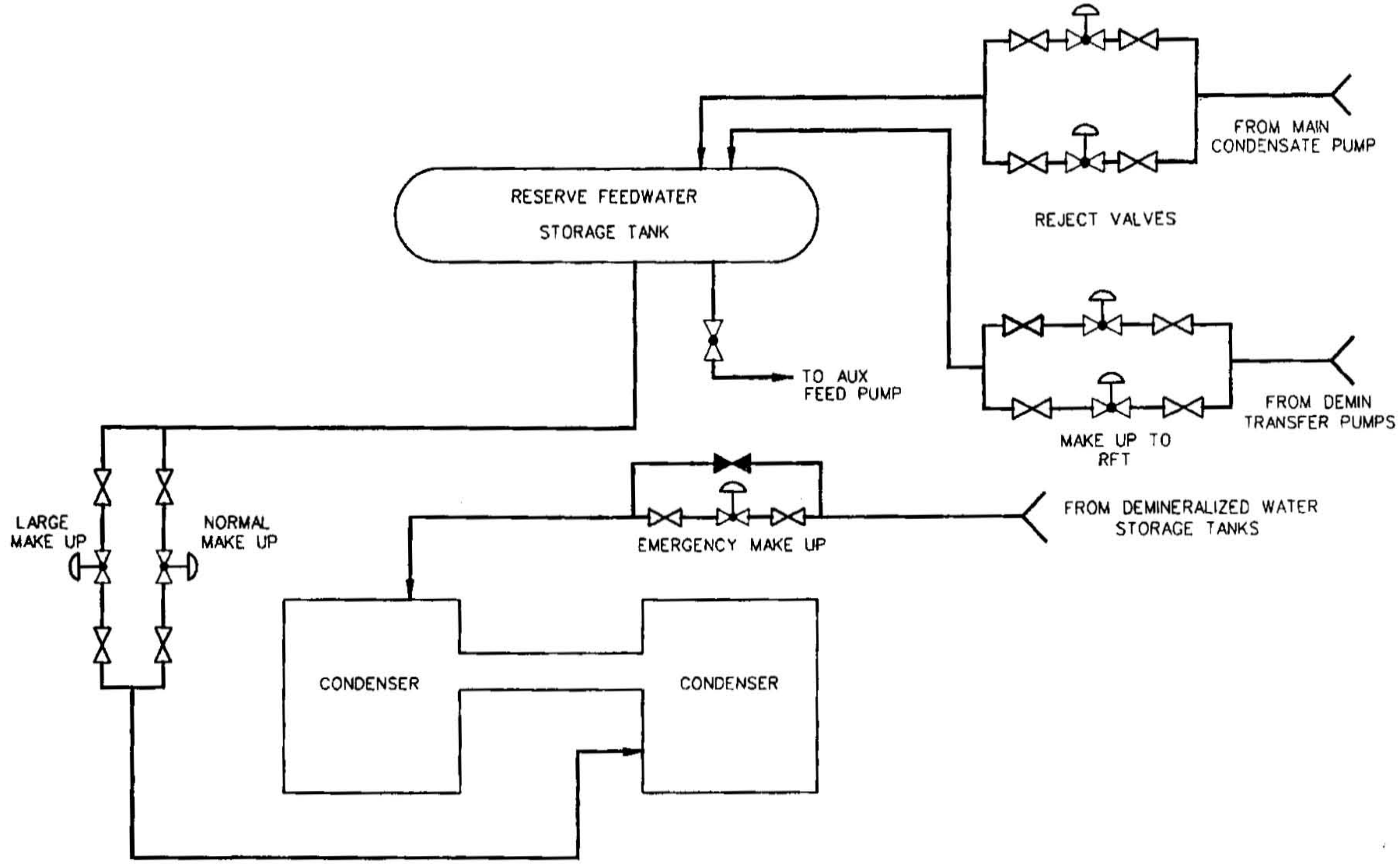


**Figure 10.5-2b Condensate Make Up and Reject System**

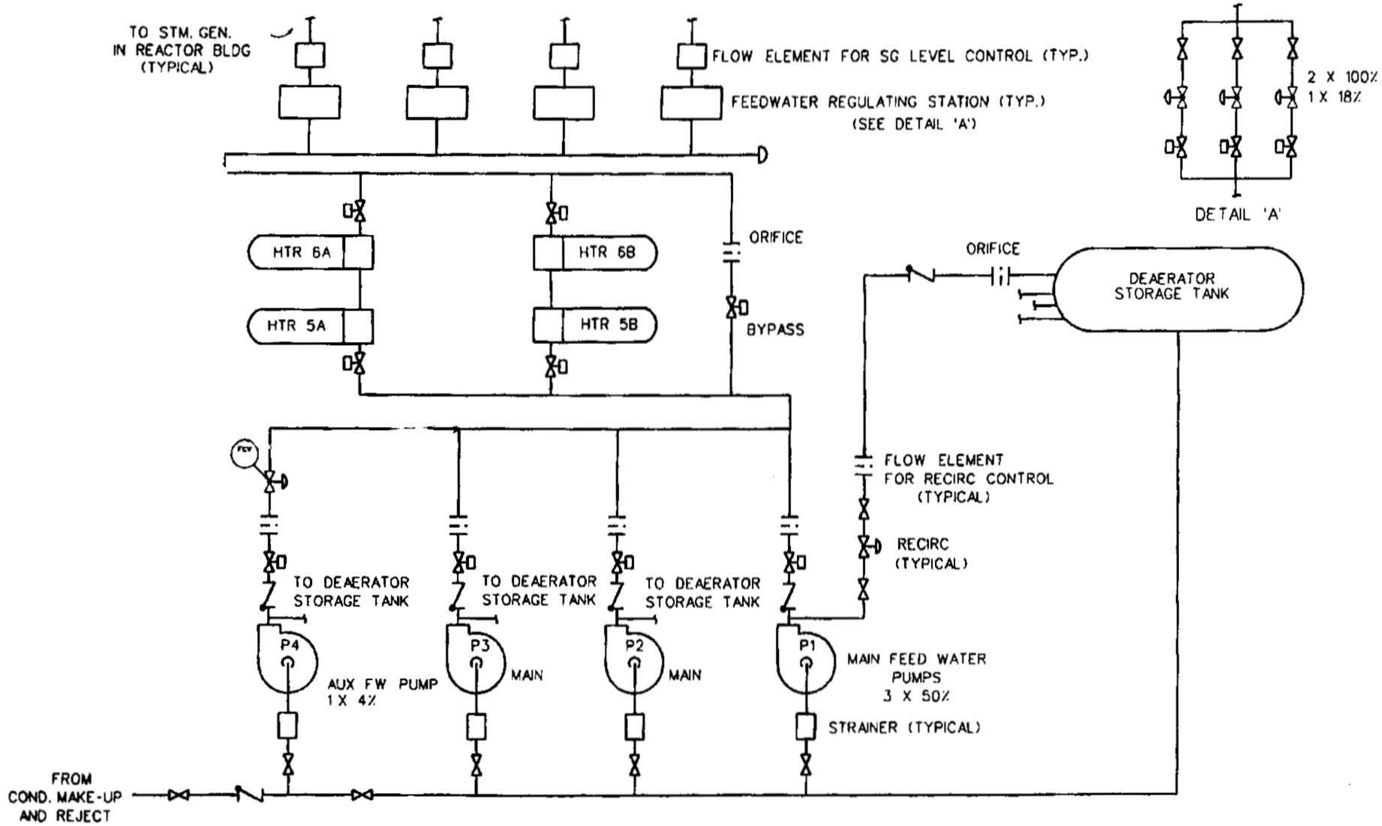


**Figure 10.5-2c Main Feedwater System**

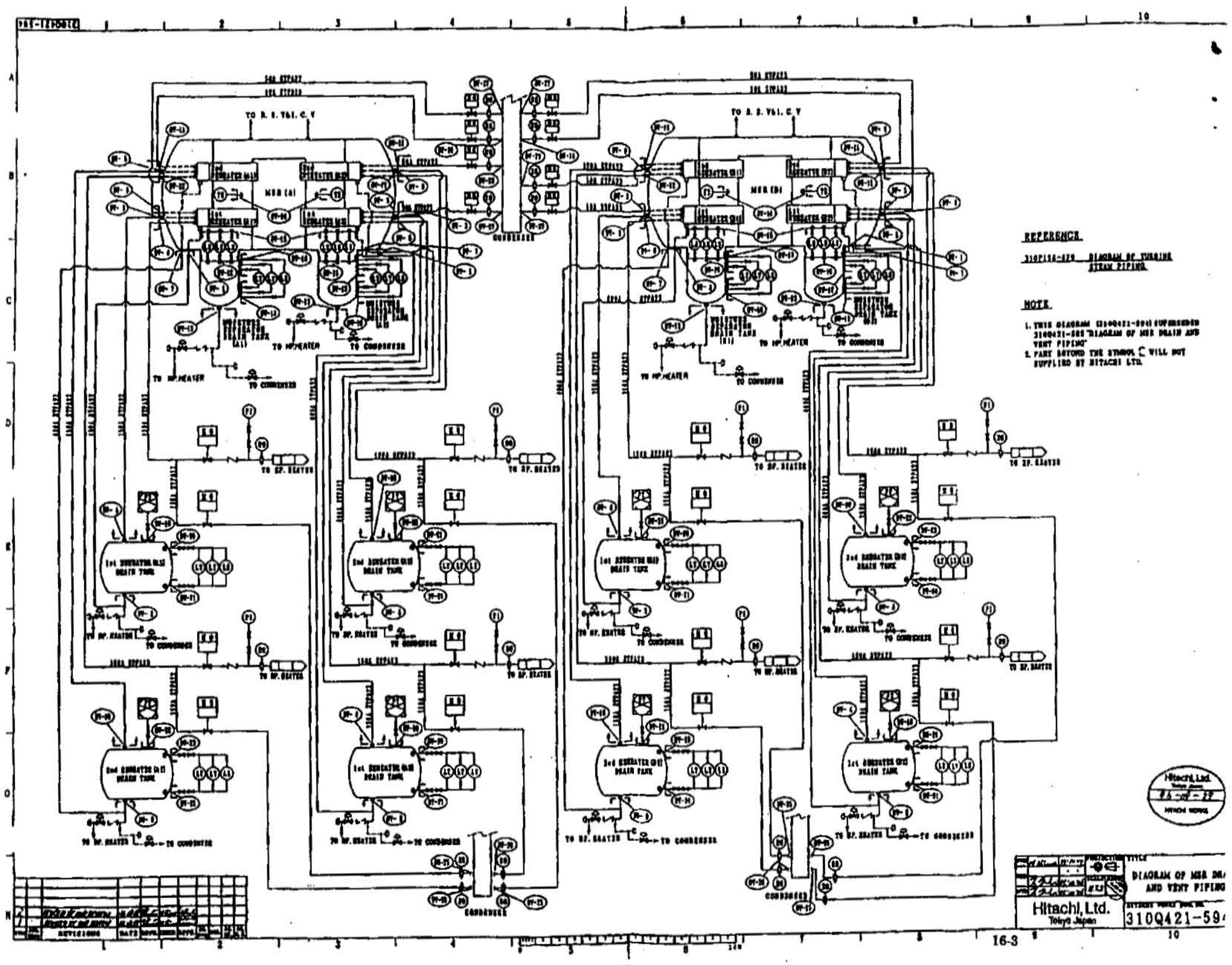


**Figure 10.5-3 Moisture Separators/Reheaters**

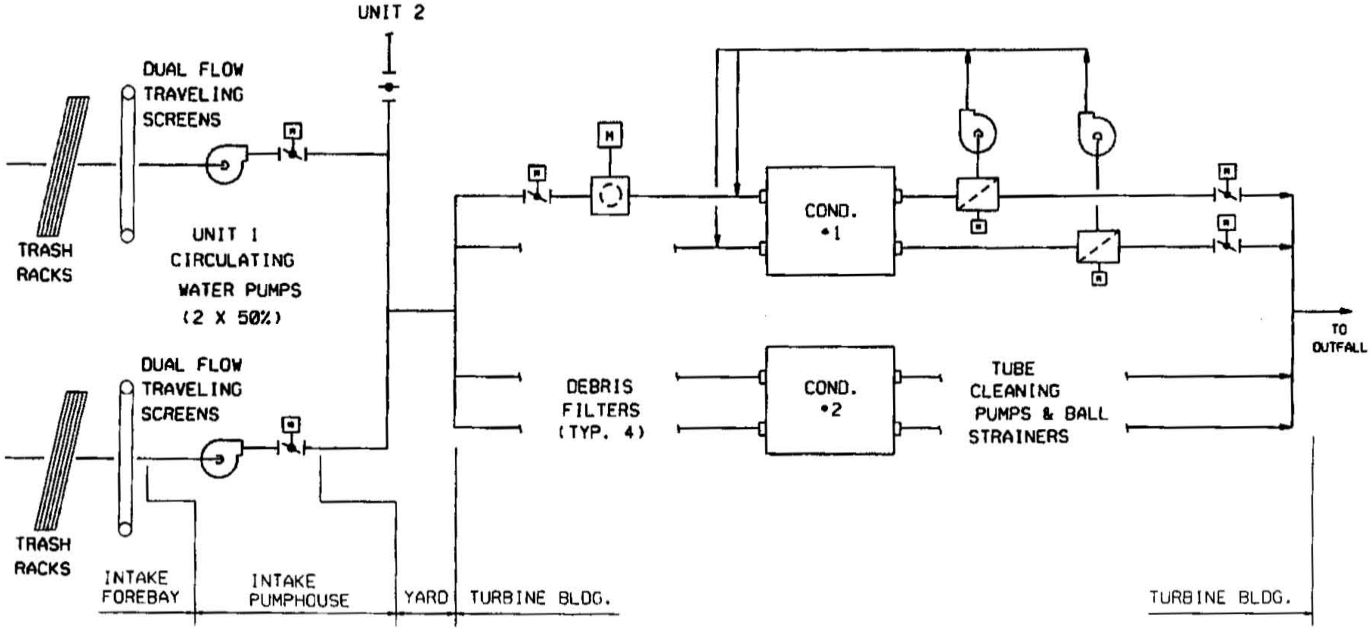


**Figure 10.6-1 Circulating Water System**