Marine Steam Turbine Plant
Warming-up Operation

MHRIJ
The Maritime Human Resource Institute, Japan

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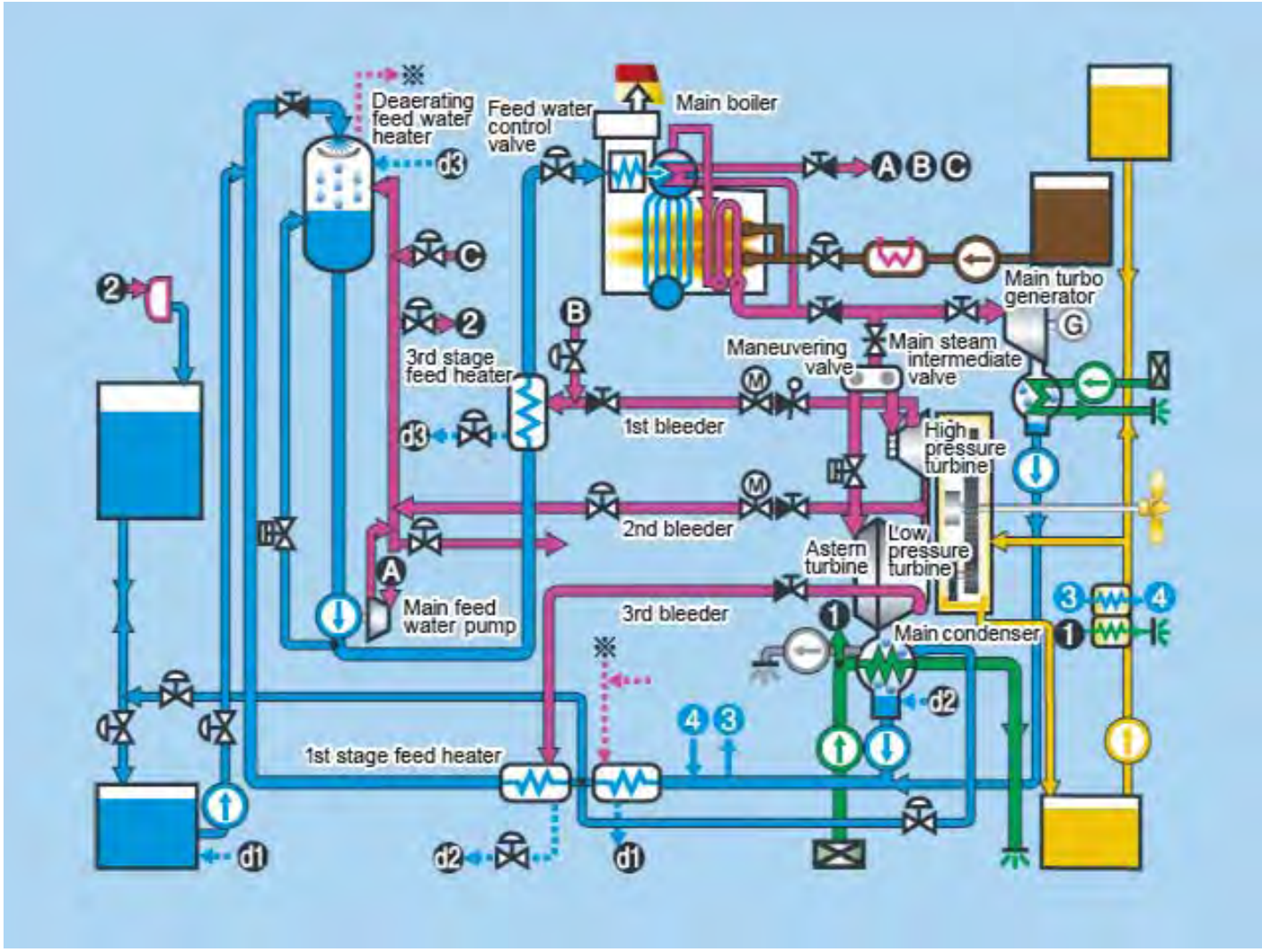
Overall steam turbine system configuration



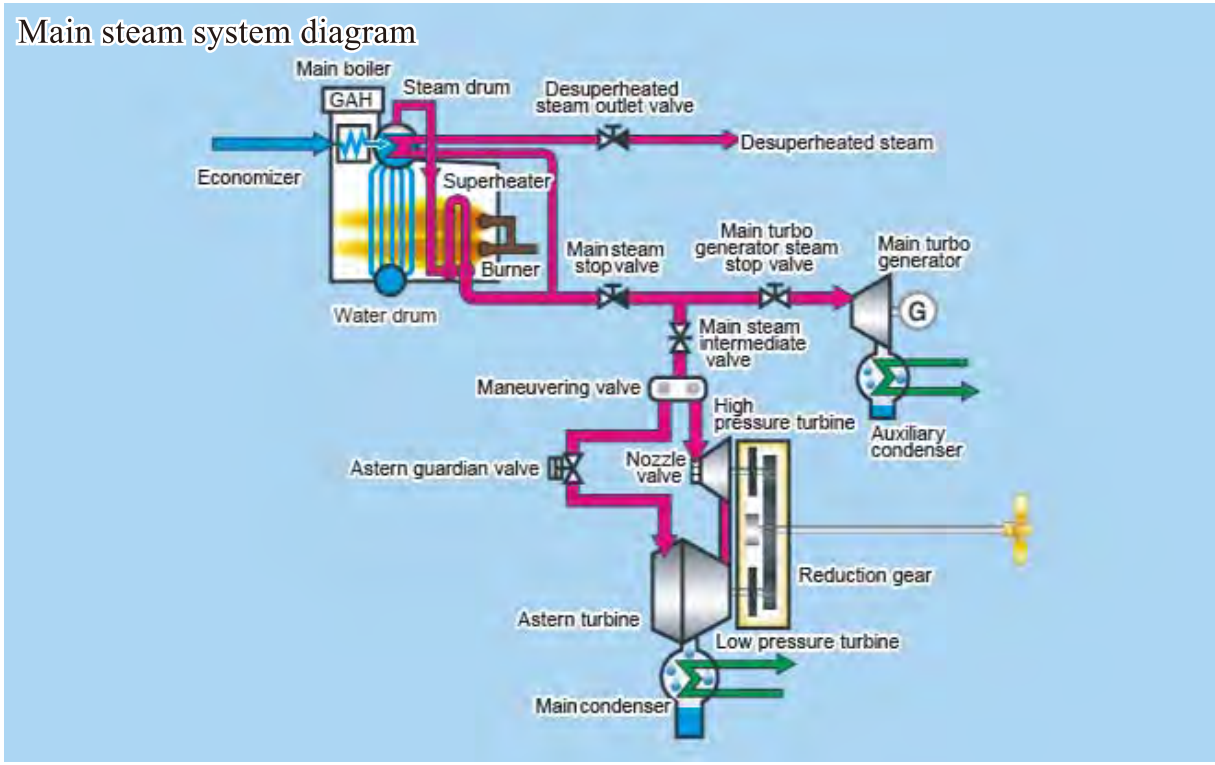
Chapter 1: Steam Turbine Systems

1. Outline of Marine Steam Turbine Plant

A marine steam turbine plant is machinery to propel ships by driving a steam turbine with steam generated in a boiler and transmitting the rotational force to a propeller shaft. To operate this plant efficiently, two types of steam - superheated steam and desuperheated steam are generated in the boiler. The superheated steam is used to drive a main turbine and main turbo generator, and the desuperheated steam is used to serve a wide variety of purposes such as driving a main feed water pump and feed water heating. After completing its tasks, the steam is collected as water and is supplied to the boiler again as feed water. While this series of processes (a cycle) is mainly supported by the main steam system, condensate water system and feed water system, other systems such as desuperheated steam system, steam bleed system and feed water make-up system are added to enhance the plant's overall thermal efficiency. Thus the whole marine steam turbine plant is formed by combining all these systems.

2. Main Steam System

Main steam system diagram



Superheater:

When saturated steam generated in the steam drum is reheated in the superheater, only its temperature is raised but its pressure remains constant, which means that the saturated steam turns into superheated steam with higher heat energy.

Maneuvering valve:

The maneuvering valve consists of ahead and astern maneuvering valves and regulates the pressure and flow of steam entering the main turbine and determines the direction of the turbine's rotation.

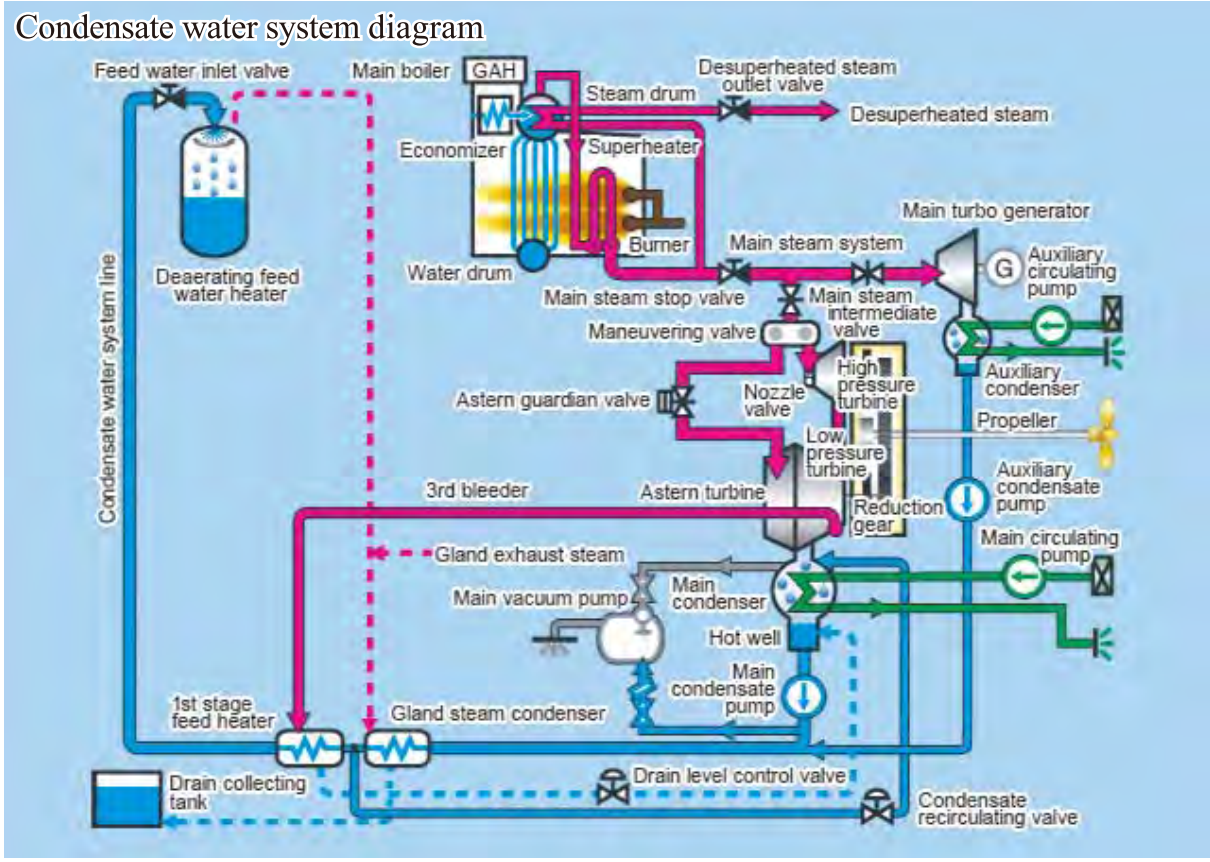
Nozzle valve:

Located at steam inlet of the high-pressure turbine casing, nozzle valves are used to adjust the ship's service speed by regulating the steam flow entering the high-pressure turbine - adjustment being made by the number of nozzles belonging to nozzle valves in use.

Reduction gear:

The reduction gear reduces the main turbine rotational speed to an adequate rotational speed for the propeller.

3. Condensate Water System



Main condenser:

The main condenser turns exhaust steam coming out of the low-pressure turbine's exhaust space back into water, cooling the steam with seawater from the main circulating pump. This water, known as condensate water, is collected in the hot well located at the bottom of the main condenser.

Vacuum pump:

The vacuum pump maintains a vacuum inside the main condenser by pumping out air and non-condensable gas to achieve maximum performance of steam and efficient condensation.

Main condensate pump:

The main condensate pump sucks in condensate water in the hot well, and sends it to the deaerating feed water heater after letting it pass through the gland condenser and first-stage feed heater.

Gland condenser:

As its heat source for heating condensate water, the gland condenser uses leak-off steam (gland exhaust steam) and so forth from gland sections of the main turbine and main turbo generator turbine. Gland exhaust steam, etc. resulting from heating of condensate water becomes drain, which is guided into the drain collecting tank. The gland condenser is of an integral construction with the first-stage feed heater.

In addition to the gland exhaust steam, leak-off steam from gland sections of the maneuvering valve and astern guardian valve, and mist inside the deaerating feed heater and drain collecting tank are guided into the gland condenser.

First-stage feed heater:

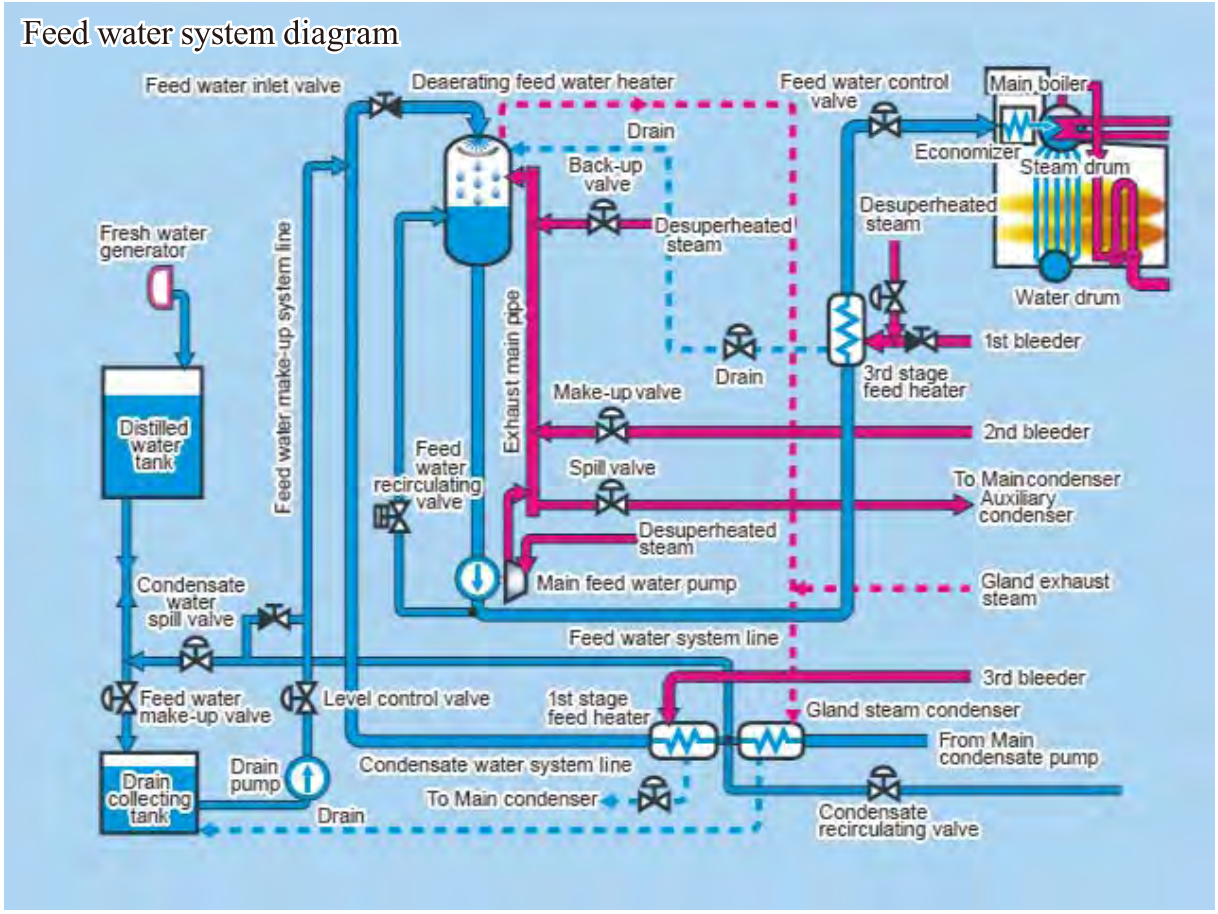
The first-stage heater heats condensate water with steam (3rd bleeder) from the low-pressure turbine. Having heated condensate water, the steam becomes drain and is guided into the main condenser hot well.

The first-stage feed heater is of an integral construction with the gland condenser.

Condensate water circulating valve:

The condensate water re-circulating valve regulates the flow of condensate water returning to the main condenser from the gland condenser outlet to keep the hot well level constant.

4. Feed Water System



Deaerating feed water heater:

The deaerating feed water heater removes dissolved oxygen from condensate water while also serving as the second-stage feed heater to heat the condensate water. This equipment consists of two sections: a deaerating chamber and a water storage tank. Condensate water is sprayed directly into the deaerating chamber through a nozzle attached to the upper part of it to deaerate dissolved oxygen, etc. while heating the condensate water by using steam from the exhaust main pipe.

Deaerated, heated condensate water is collected in the water storage tank at the bottom of the equipment. Drain from the third-stage feed heater and that from heat exchangers are also guided into the water storage tank. The tank's level is controlled within a prescribed range to regulate excess or shortage of water within the entire cycle.

Exhaust main pipe:

The exhaust main pipe stores exhaust steam from the feed water pump and steam extracted from the second bleeder. While being kept at a constant pressure, the steam inside the pipe is sent to the deaerating feed heater as a heat source.

To maintain the constant pressure within the pipe, the exhaust main pipe has a make-up valve, back-up valve and spill valve.

Feed water pump:

The main feed water pump is a steam turbine-driven pump. It uses a governor to automatically control its rotation so that the feed water pressure can be kept constant even when the feed water flow changes.

The main feed water pump pressurizes feed water from the water storage tank of the deaerating feed heater and sends it to the steam drum via the third-stage feed heater, feed water control (FWC) valve and economizer.

Third-stage feed heater:

The third-stage heater heats highly pressurized feed water to the boiler.

When the ship is in port, desuperheated steam is used for heating, but when at sea, the first bleeder is used to heat the feed water to increase thermal efficiency.

After having heated feed water, the bleeder or desuperheated steam becomes drain and is guided into the deaerating feed heater.

Feed water control (FWC) valve:

The feed water control (FWC) valve controls amount of feed water by detecting water level and steam flow to keep the steam drum water level constant.

Economizer:

The economizer is one of the pieces of boiler structural equipment. It heats feed water with combustion gas that came after heating the boiler main bank.

Make-up feed water system:

Some loss of water inevitably accompanies a turbine plant. The make-up feed water system makes up for such loss. Since the water levels of the condenser and the boiler are kept constant, make-up feed water is supplied by detecting changes in the water level of the deaerating feed water heater.

Distilled water tank:

The distilled water tank stores distilled water generated from seawater or fresh water of fresh water tank by fresh water generator.

Drain collecting tank:

The drain collecting tank collects drain from various sections of the plant while also storing make-up feed water from the distilled water tank temporarily.

Drain pump:

The drain pump sends drain in the drain collecting tank to the deaerating feed heater as make-up feed water.

Feed water make-up valve:

As the deaerating feed heater level drops, the feed water make-up valve opens, sending distilled water in the distilled water tank to the drain collecting tank.

Drain collecting tank level control valve:

To keep the drain collecting tank level constant, this valve controls the flow of drain which is being sent to the deaerating feed heater by the drain pump.

Condensate water spill valve:

As the deaerating feed water heater's water level rises, the condensate water spill valve opens to allow some of the condensate water that has come out of the gland condenser to escape into the distilled water tank.

5. Desuperheated Steam System

Desuperheated steam refers to steam the temperature of which is lowered by letting the steam pass through the desuperheater in the steam drum. It is used in the following equipment:

Uses of desuperheated steam:

① Driving main feed water pump
② Heating third-stage feed heater while in port
③ Backup for pressure drop in exhaust main pipe
④ Gland steam for main turbine and main generator turbine
⑤ Main engine warming-up steam
⑥ Heating lay-up boiler
⑦ Assist steam for boiler burner
⑧ Boiler soot blower
⑨ Heating low-pressure steam generator

(Reference)

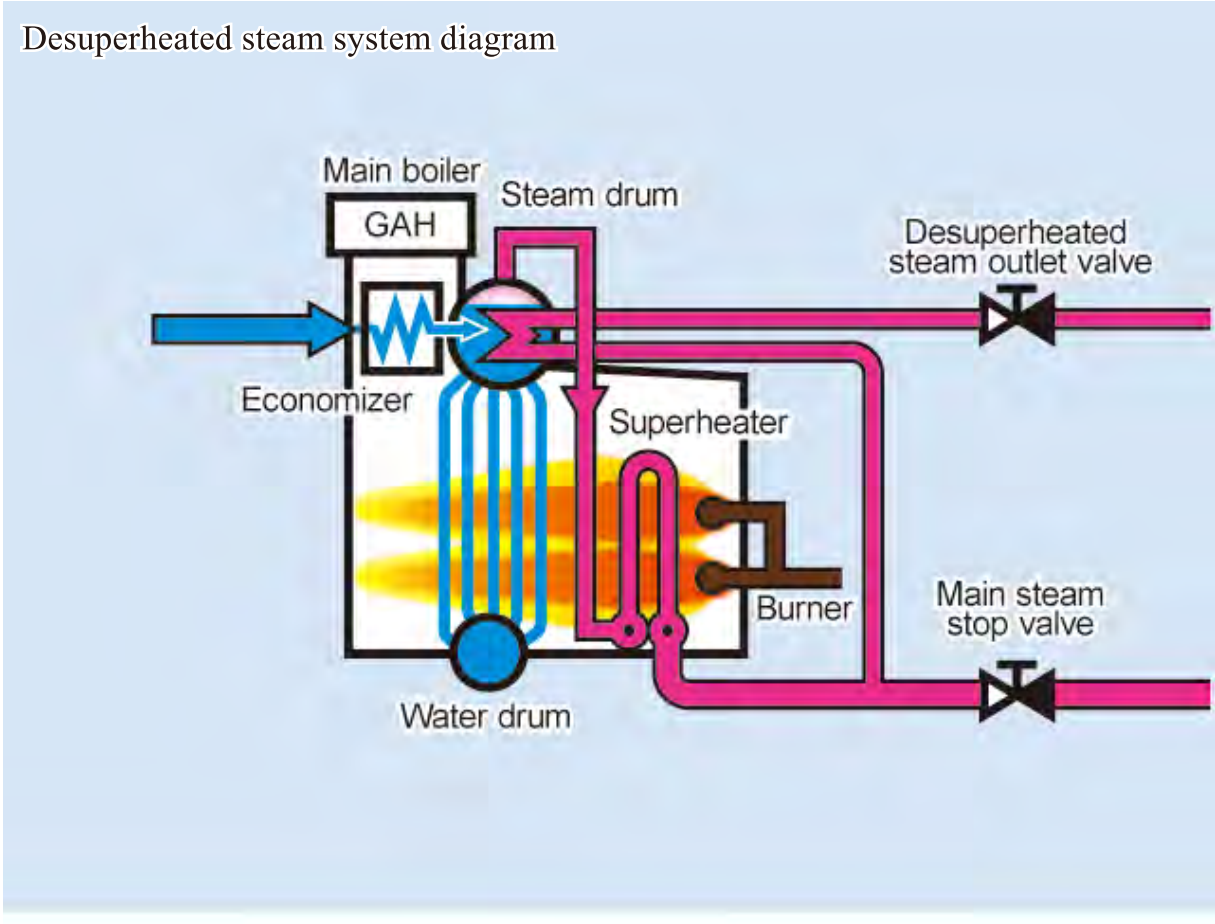
Low-pressure steam generator (LPSG):

The LPSG generates low-pressure, saturated steam using desuperheated steam as a heat source. It is provided to separate the main boiler feed water system from those general-service steam systems that may possibly contain oil and other impurities.

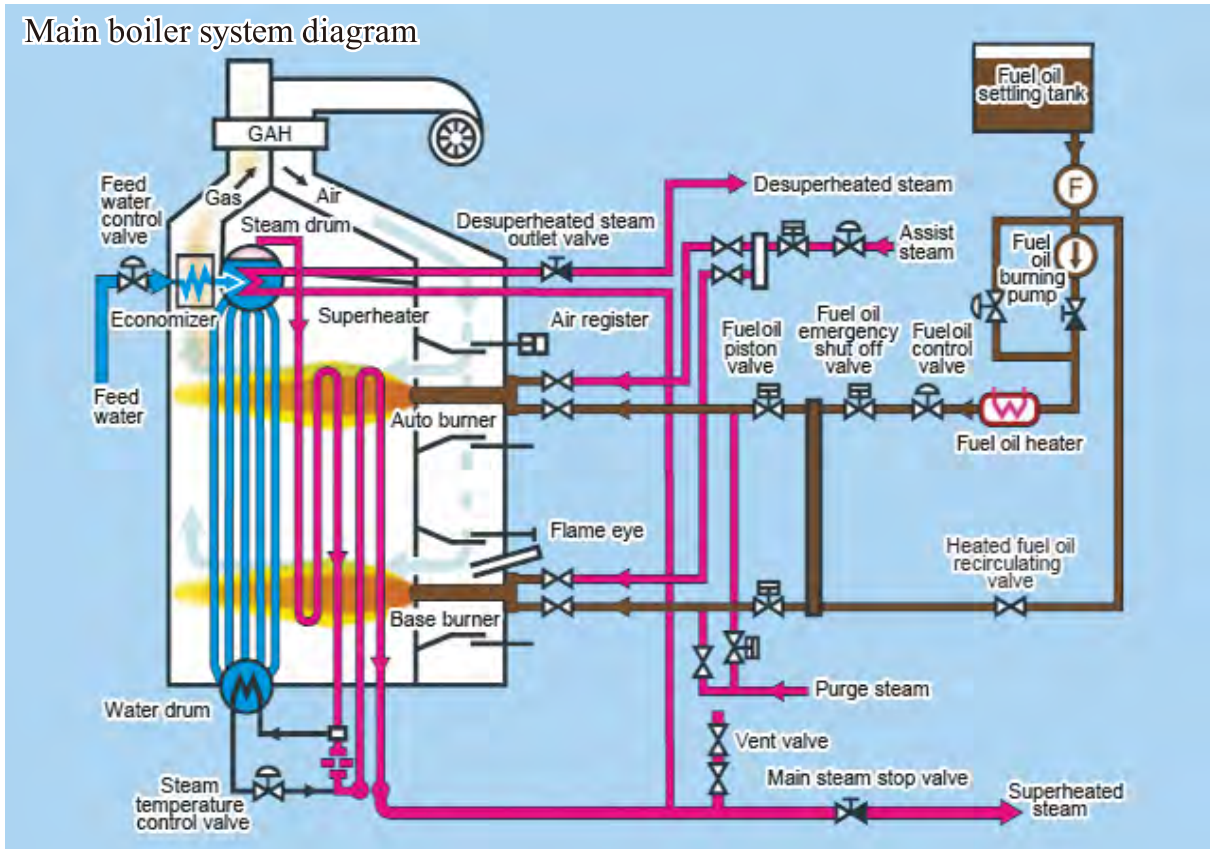
Exhaust steam, condensate water, drain:

Desuperheated steam exhaust, condensate water and drain are collected in any one of the main condenser, auxiliary condenser, deaerating feed water heater, or drain collecting tank.

Desuperheated steam system diagram



6. Main Boiler



Boiler structure:

The boiler structure comprises the steam drum; water drum; main bank; furnace where fuel oil is burned; water wall that constitutes the furnace; water wall header; superheater that heats saturated steam; screen tube placed between the furnace and superheater; downcomer to enable boiler water to circulate naturally and smoothly; riser that connects the superheater header to steam drum; and economizer that heats feed water entering the steam drum; among others.

Attached equipment:

Attached equipment include: combustion unit, gas air heater (GAH), forced draft fan (FDF), soot blower and automatic combustion control (ACC) equipment.

Fuel oil (FO) settling tank:

The fuel oil settling tank heats the boiler fuel oil and lets it settle to precipitate impurities.

Fuel oil (FO) burning pump:

The fuel oil burning pump pressurizes fuel oil to a suitable pressure for atomization before sending it to the boiler burner.

Fuel oil (FO) heater:

The fuel oil heater uses steam to heat fuel oil and provide it with viscosity most suitable for atomization from the burner.

Fuel oil (FO) control valve:

This valve controls the flow of fuel oil to be sent to the burner.

Fuel oil (FO) emergency shut-off valve:

This valve shuts off fuel oil in the event of danger to the boiler - emergencies such as flame failure and significant drop in water level.

Fuel oil (FO) piston valve:

This valve automatically shuts off or passes fuel oil to be atomized from the burner.

Fuel oil (FO) heating-circulating valve:

This valve is opened to set up a circulating line before the boiler is ignited. FO can be heated by means of FO heater, circulating the line up to the FO piston valve inlet.

Base burner:

The base burner continually burns fuel oil regardless of boiler load.

Auto burner:

The auto burner is automatically ignited or extinguished according to boiler load.

Flame eye:

The flame eye keeps an eye on the existence of flame. Should the flame be lost, the flame eye makes an alarm and protection devices work at the same time.

Assist steam

The assist steam assists fuel oil spraying from the burner. It is sprayed from circumference of the fuel oil nozzle.

Purge steam:

After the burner has been extinguished, the purge steam purges remaining fuel oil in the burner body.

Forced draft fan (FDF):

The forced draft fan (FDF) supplies air required for combustion into the furnace. The amount of air to be supplied is controlled by opening the FDF inlet vane.

Gas air heater (GAH):

The gas air heater (GAH) heats the air required for combustion with combustion gas that came after heating the economizer. Heating elements rotate passing through the gas side and air side of the casing. As the elements heated in the gas side enter the air side, the air supplied by the forced draft fan is heated.

Air register damper:

When extinguishing the burner, this damper is closed to shut off the supply of air required for combustion.

Steam temperature control (STC) valve:

The STC valve maintains steam temperature at the superheater outlet at a setting value by controlling the flow of superheated steam that passes through the desuperheater for temperature-control.

Desuperheated steam:

Some of the superheated steam is sent to the desuperheater in the steam drum, where its temperature is lowered by heat exchange with the saturated water in the drum. This lower-temperature superheated steam is called desuperheated steam.

Automatic combustion control (ACC):

The automatic combustion control (ACC), which detects steam pressure and flow and fuel oil flow, maintains the superheated steam pressure at a setting value by controlling the opening of the fuel oil flow control valve and the forced draft fan inlet vane.

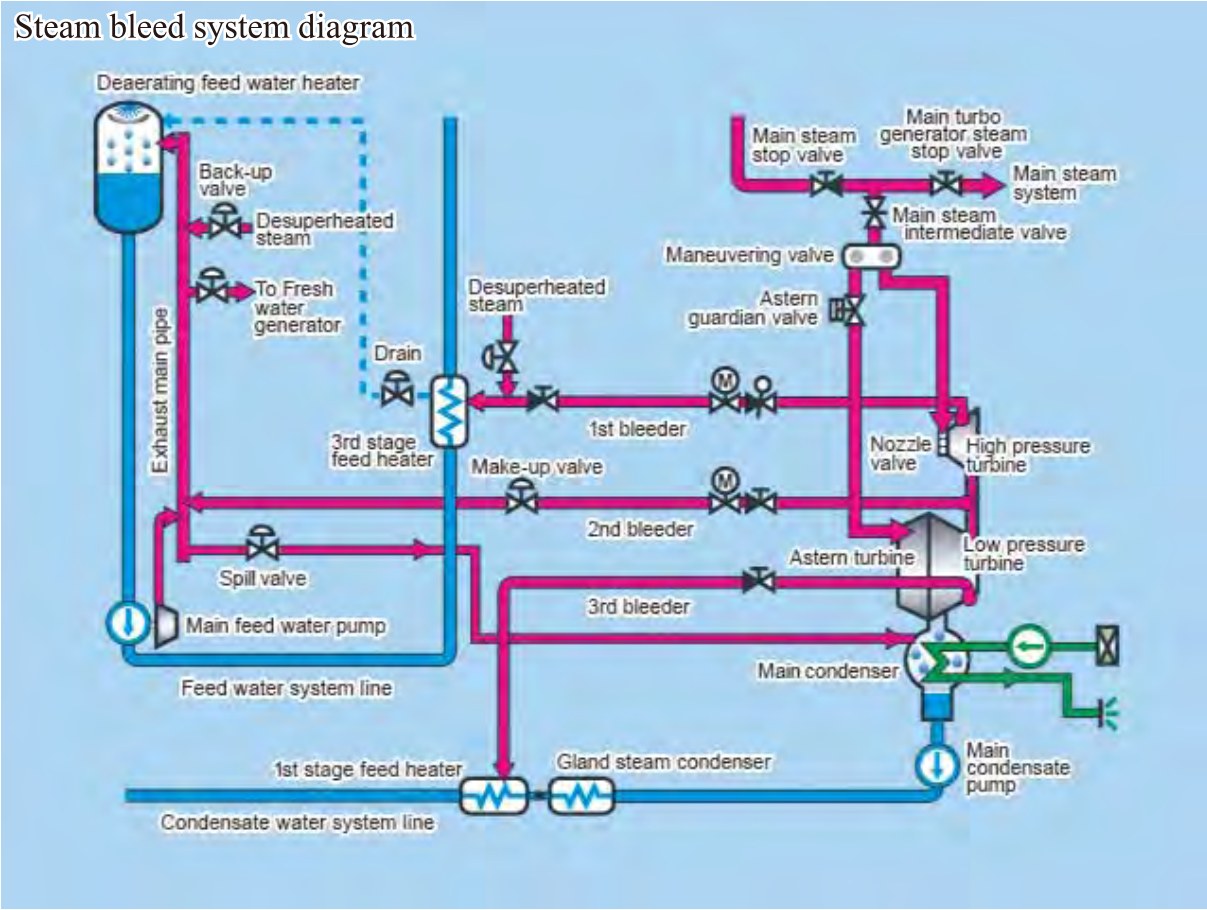
Steam temperature control (STC):

The steam temperature control (STC), which detects steam temperature and air flow, maintains the superheated steam temperature of the superheater outlet at a setting value by controlling the opening of the STC valve.

Feed water control (FWC):

The feed water control (FWC), which detects the steam drum level and steam flow, maintains the steam drum water level at a setting value by controlling the opening of the FWC valve.

7. Steam Bleed System



Steam bleeding:

Steam bleeding is carried out when the main engine load is higher than the prescribed value. The bled steam is used as a heat source for feed water. Since this reduces the quantity of heat discarded in the condenser, it can enhance the entire turbine plant's thermal efficiency.

Steam bleeding is also effective for reducing internal loss that increases as the steam expands inside the main turbine.

First bleeder:

The first bleeder refers to steam extracted from the third stage of the high-pressure turbine to serve as a heat source for the third-stage feed water heater.

Drain from the third-stage feed water heater is sent to the deaerating feed heater.

Second bleeder:

The second bleeder refers to steam extracted from the receiver pipe connecting the high-pressure and low-pressure turbines, which is guided into the exhaust main pipe.

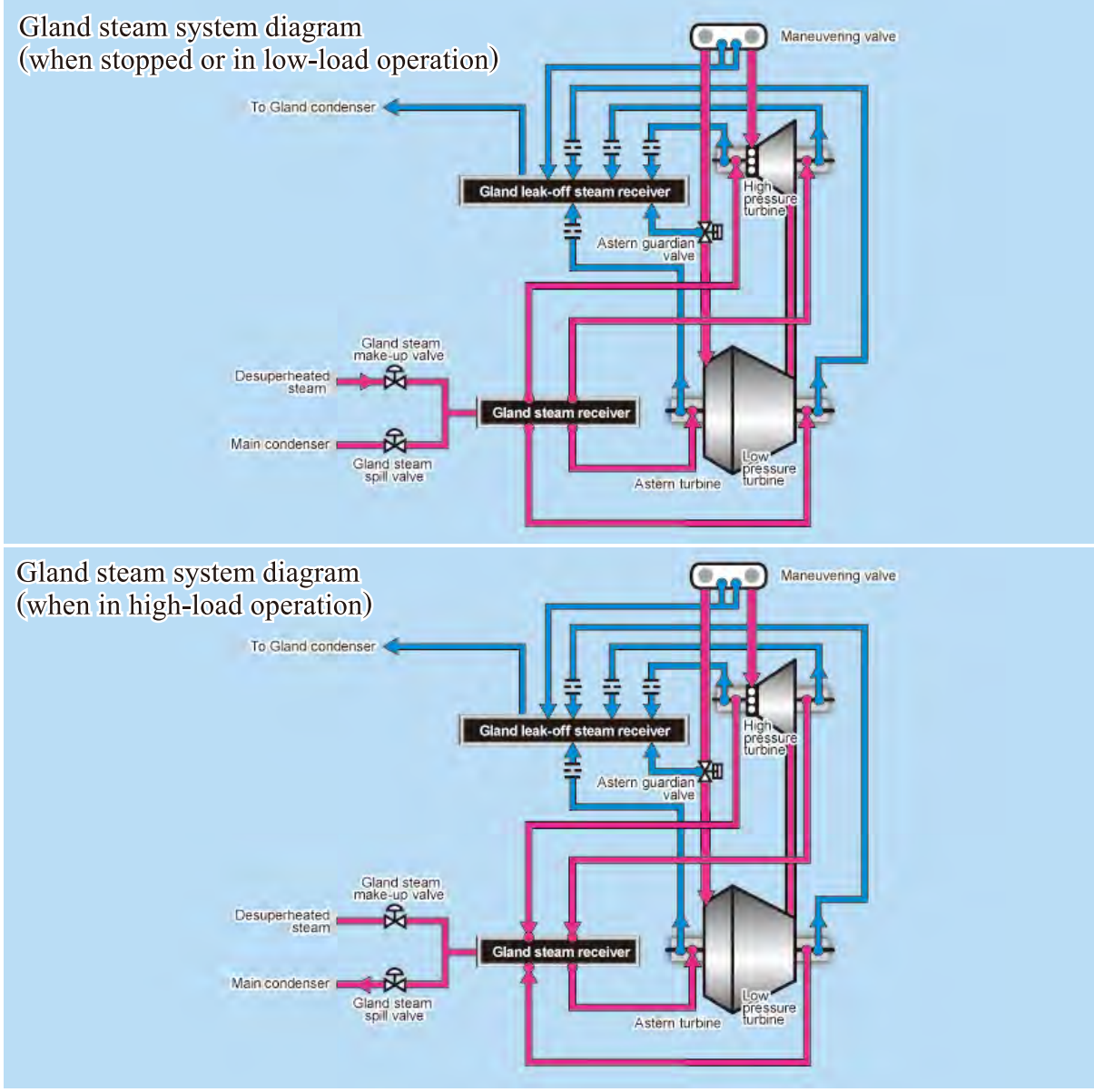
A make-up valve is provided along the route to the exhaust main pipe. The valve controls the second bleeder flow to keep the exhaust main pipe pressure constant.

Third bleeder:

The third bleeder refers to steam extracted from the third stage of the low-pressure turbine to serve as a heat source for the first-stage feed water heater.

Drain from the first-stage feed water heater is sent to the main condenser.

8. Gland Steam System



Gland steam:

Labyrinth packing - an airtight device that prevents steam leakage and air penetration into the turbine interior - is installed in four gland sections where the main turbine rotors pass through the turbine casings. Air-tightness is maintained by providing the packing with gland steam.

Gland steam receiver:

Sitting between the high-pressure turbine and low-pressure turbine, the gland steam receiver keeps the gland steam supply pressure constant.

Gland steam make-up valve:

When the turbine is stopped or in low-load operation, a large amount of gland steam is sucked into the turbine casing, which lowers the gland steam pressure. Then the gland steam make-up valve opens to provide the gland steam receiver with desuperheated steam.

Gland steam spill valve:

When the turbine is in high-load operation, since the turbine's internal pressure is high, the amount of leak-off steam from the interior of the gland section increases, raising the gland steam pressure. Then the gland steam spill valve opens to allow gland steam to escape from the gland steam receiver to the main condenser.

Gland leak-off steam receiver:

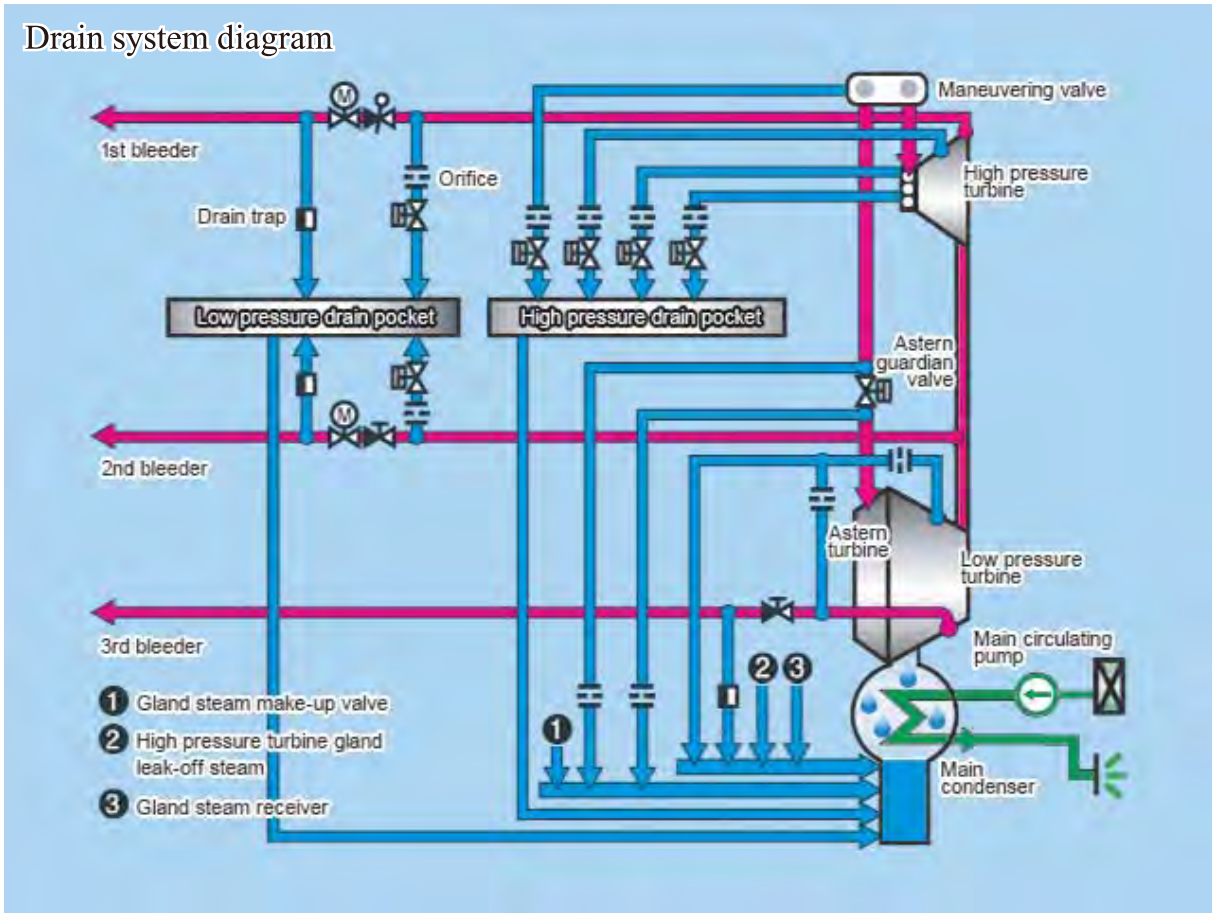
Installed between the high-pressure turbine and low-pressure turbine, the gland leak-off steam receiver collects leak-off steam from outside of the labyrinth packing. The receiver also collects gland leak-off steam from the maneuvering and astern guardian valves.

The gland leak-off steam guided into the gland condenser with its negative pressure made by the gland exhaust fan, becomes drain, and then is collected in the drain collecting tank.

9. Drain System

During start-up or low-load operation of a steam turbine, some of operating steam is cooled in the turbine and becomes drain.

Since the drain thus generated can cause drain attack and damage the turbine, necessary devices and piping are provided to discharge it from the turbine casings, steam pipe lines and other sections.



Drain pocket:

The drain pocket collects drain from various sections and send it to the main condenser. There are two types of drain pocket: a high-pressure drain pocket and low-pressure drain pocket.

Drain valve:

The drain valves are mainly provided in high-pressure drain lines and open during low-load operation when drain is prone to be generated.

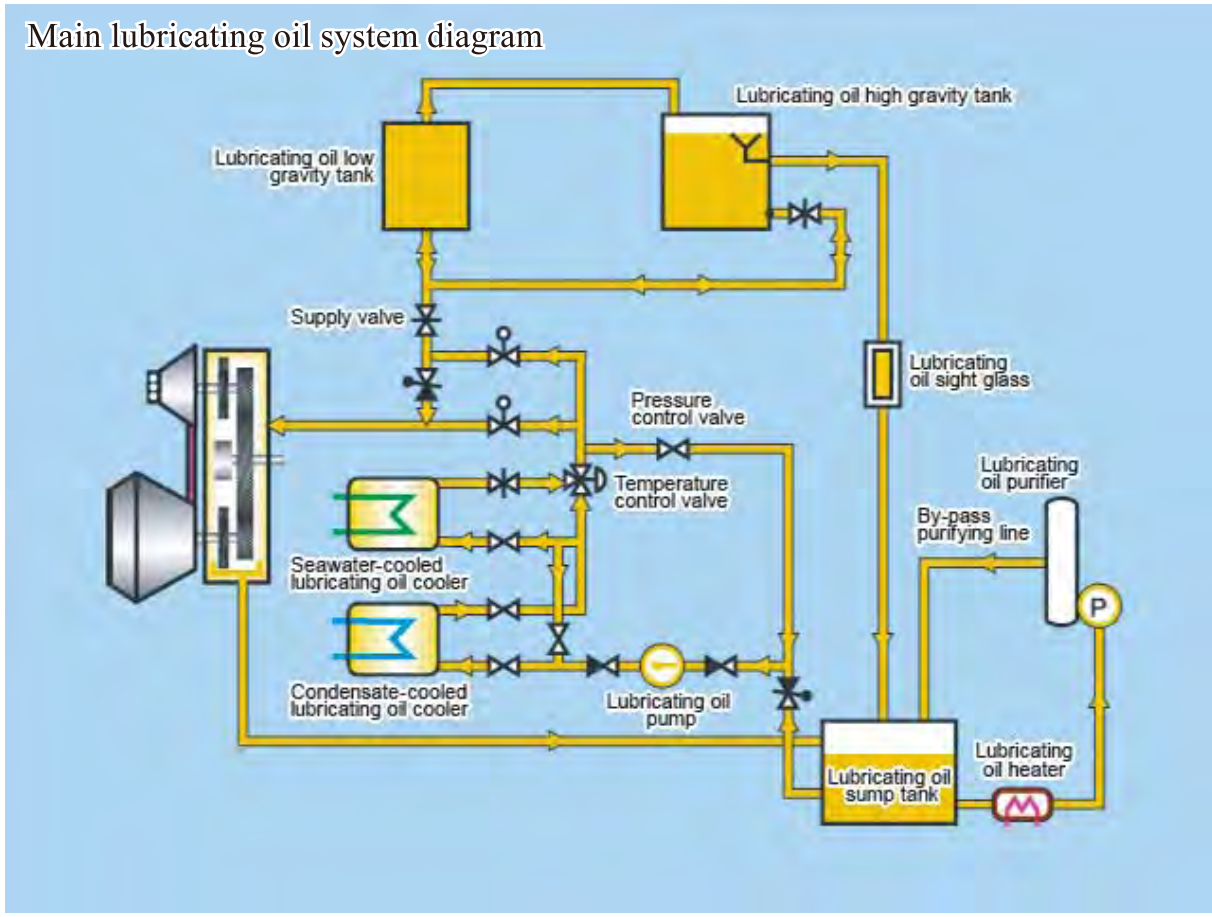
Drain trap:

The drain trap automatically lets drain pass but prevent passage of steam.

Orifice:

The orifice limits the amount of steam that leaks together with drain.

10. Main Lubricating Oil System



Main lubricating oil (LO) pump:

The main lubricating oil (LO) pump supplies lubricating oil to the main turbine bearings, reduction gear bearings, reduction gear, and flexible coupling tooth flanks, among others.

Lubricating oil (LO) cooler:

There are two types of LO cooler: seawater-cooled and condensate-cooled LO coolers. When using the condensate-cooled LO cooler, it is possible to recover exhaust heat.

Temperature control valve:

The temperature control valve keeps the LO temperature constant at the main turbine inlet by controlling the ratio between the lubricating oil passing the cooler side and that passing the by-pass side.

Lubricating oil (LO) gravity tank:

Should the main LO pump stop due to a blackout, etc., the LO gravity tanks in the upper part of the engine room ensure lubricating oil supply to the main turbine and reduction gear until inertia rotation of the turbine stops.

Sight glass:

The sight glass is used to confirm if there is overflow of the LO gravity tanks. While the LO pump is running, lubricating oil is supplied to the gravity tanks at all times, filling them to overflow with lubricating oil.

By-pass purifying line:

Independent of the LO pump line, the by-pass purifying line is provided with an LO purifier. The LO purifier continually purifies and circulates LO in the LO sump tank through the by-pass purifying line.

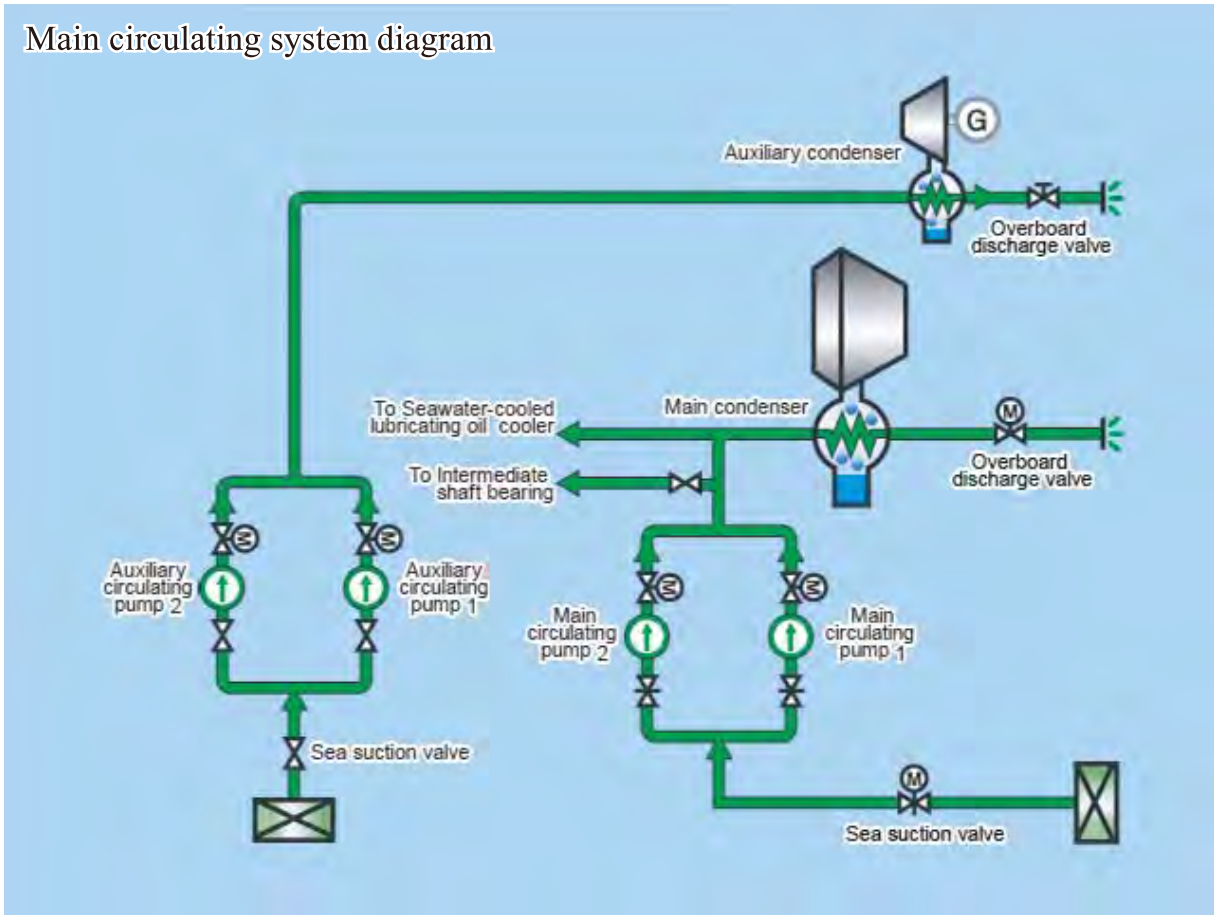
A heater is provided at the purifier inlet to reduce viscosity of the LO to an appropriate value, which ensures effective purification as well.

Control oil/operating oil:

Some of the lubricating oil is used as control oil for the maneuvering unit and safety devices, and operating oil for engaging/disengaging turning gear.

11. Main Circulating System

Main circulating system diagram



Main circulating pump:

The main circulating pump sends seawater for cooling the main condenser.

Auxiliary circulating pump:

The auxiliary circulating pump sends seawater for cooling the auxiliary condenser.

Auxiliary condenser:

The auxiliary condenser cools exhaust steam of the main generator turbine with seawater from the auxiliary circulating pump, and turns it into water.

Chapter 2: Turbine Operation Preparation and Warming-up

Abrupt inflow of high-temperature steam into a cold steam turbine generates dangerous drain that can damage the turbine. It also generates excessive heat stress that gives rise to irregular expansion of the turbine rotor and casing, which can lead to serious accidents such contact between rotating and stationary sections of the turbine.

Therefore, the entire turbine must be sufficiently warmed up before being put into operation.

Steam turbine warming-up operation is largely divided into warming-up preparation, warming-up operation and trial run preparation, which should be carried out in the steps as shown below:

Turbine operation preparation: Process chart

Start lubricating oil purifier and by-pass purification:

It is necessary to supply lubricating oil to the main turbine bearings and reduction gear bearings with an appropriate viscosity. Therefore, start the LO purifier 12 hours before departure and heat lubricating oil in the LO sump tank by means of the by-pass purification line.

1. Warming-up preparation

Ignite lay-up boiler and raise pressure:

Two main boilers are operated while at sea, but one boiler is laid up while in port. So it is necessary to ignite lay-up boiler and raise its steam pressure before departure. Usually, the laid-up boiler is kept at a pressure of 1.0 MPa by supplying desuperheated steam to heating pipe in the water drum.

- Start fuel oil heating and circulating (3 hr. 45 min. before departure)
- Pre-ignition check (boiler water level and state of gas air heater operation)
- Supply assist steam and purge steam
- Stop fuel oil heating and circulation
- Initiate boiler gauge board (BGB) power supply and start pre-purge
- Open all pertinent valves
  Slightly open superheater final stage drain valve (See Fig. Ⓑ, page 21)
  Slightly open auxiliary desuperheater outlet drain valve (See Fig. Ⓒ, page 21)
  Open superheater air vent valve to 1/4 opening (See Fig. Ⓐ, page 21)
- Ignite boiler
- Set ACC (Control Room)
- Close air register damper
- Reset fuel oil shut-off valve
- Open FO piston valve's inlet valve
- Insert igniter and switch it ON
- Foot switch ON (Open FO piston valve)
- Open air register damper after confirming ignition
- Set ACC to lowest oil pressure combustion (Control Room)
- Stop boiler heating steam supply

Conduct visual inspection and initiate power supply:

- Initiate power supply for pertinent sections in Control Room
- Set main turbine expansion dial gauge at "0"

Set up main lubricating oil system:

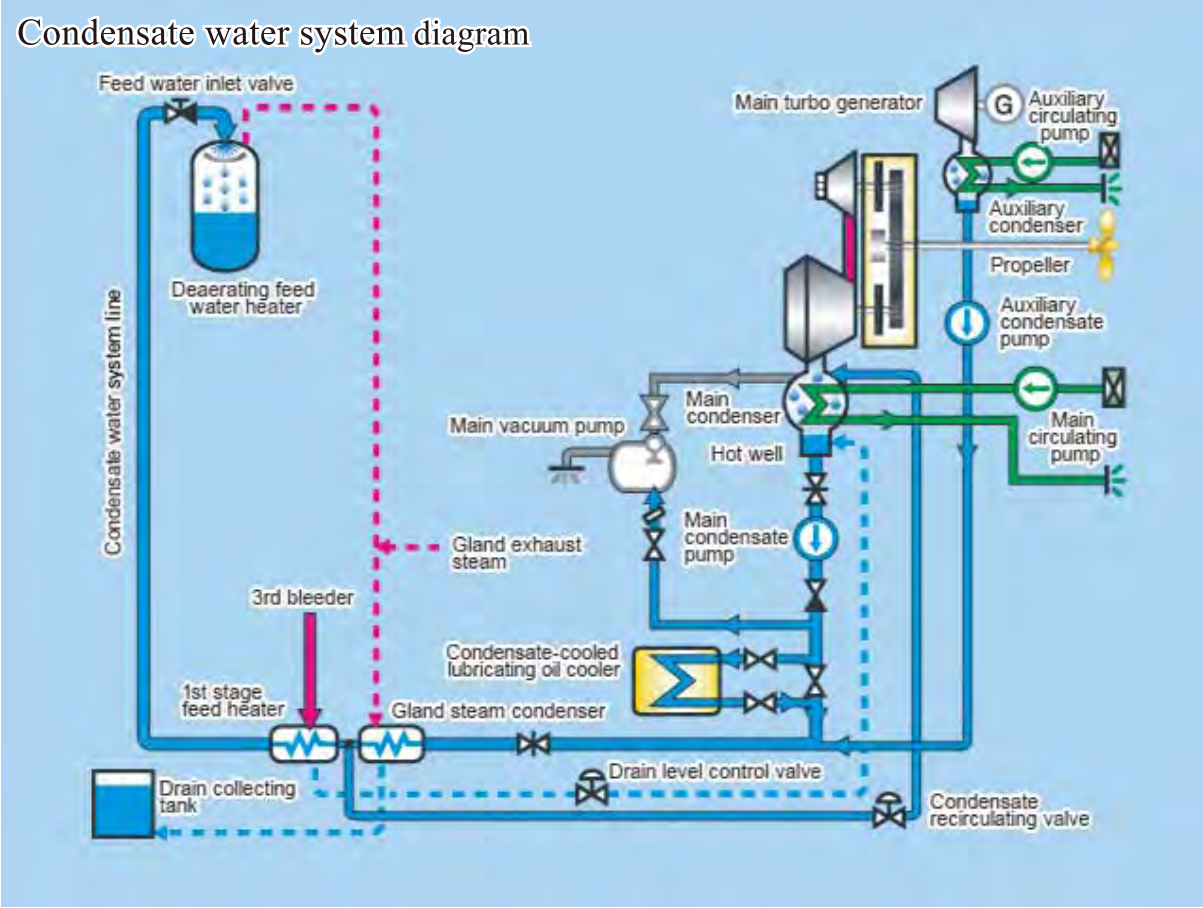
- Confirm amount of LO in the LO sump tank
- Open main LO pump suction valve, discharge valve and pressure control valve
- Start main LO pump
- Adjust discharge pressure with pressure control valve (0.44~0.49 MPa)
- Open gravity tank supply valve
- Confirm high gravity tank's overflow (with sight glass)
- Set LO temperature controller at 40℃~45℃
- Confirm LO supply to bearings and reduction gear sprayer (with sight glass)

Set up main circulating system:

- Open sea suction valve, main circulating pump suction valve and overboard valve (20% opening as to the overboard valve)
- Start main circulating pump
- Open main circulating pump discharge valve
- Conduct air purge of main condenser water side
- Open cooling seawater valves to the intermediate shaft bearings and the seawater-cooled LO cooler
- Start marine growth preventing system

Set up main condensate water system:

- Confirm main condenser hot well level
- Open pertinent valves of main condensate pump except discharge valve
- Start main condensate pump
- Open main condensate pump discharge valve
- Open condensate re-circulating valve's by-pass valve → Adjust main condenser hot well level



Test main engine control system:

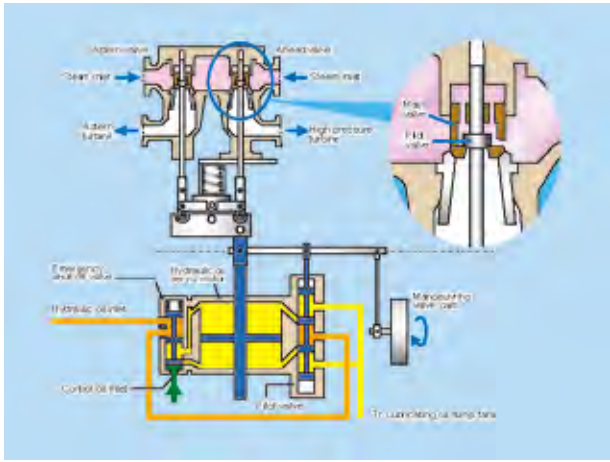
- Confirm close of the main steam intermediate valve, its by-pass valves, and 1st and 2nd bleeder manual valves
- Test 1st and 2nd bleeder valve opening/closing
- Test drain valve opening/closing
- Test astern guardian valve opening/closing
- Test maneuvering valve

Start main engine turning:

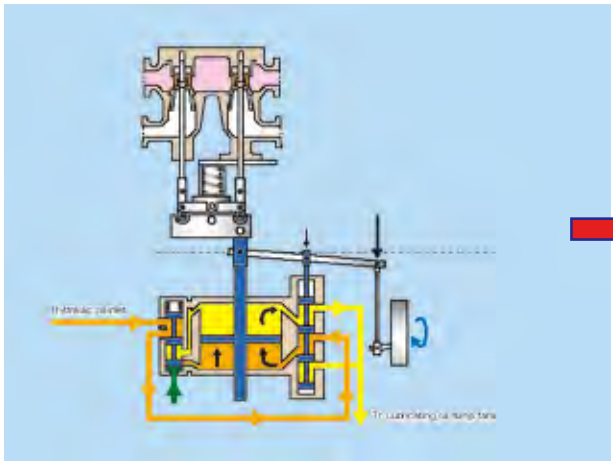
- Engage main engine turning gear and start turning
- Check electric current value to confirm that there is no mechanical malfunction on shafting

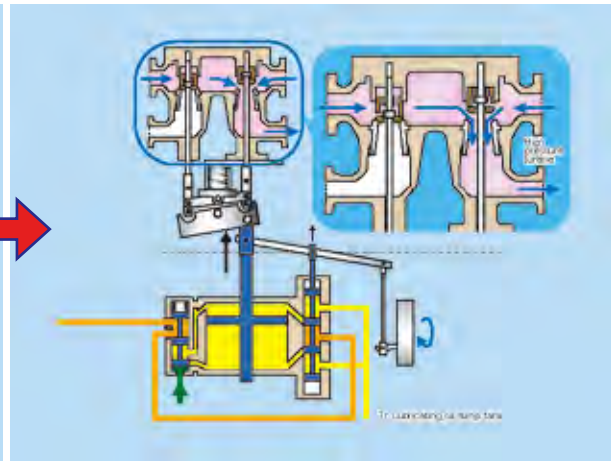
Maneuvering valve operation mechanism:

Neutral

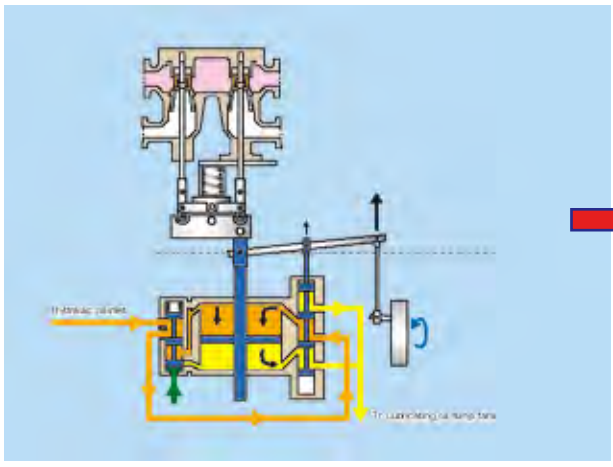


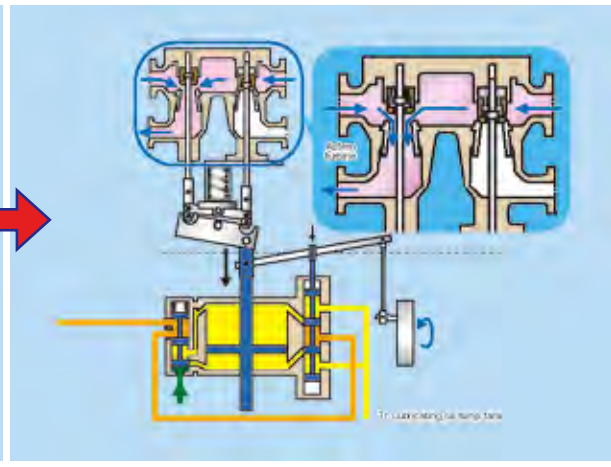
Ahead





Astern





2. Warming-up operation

Supply gland steam:

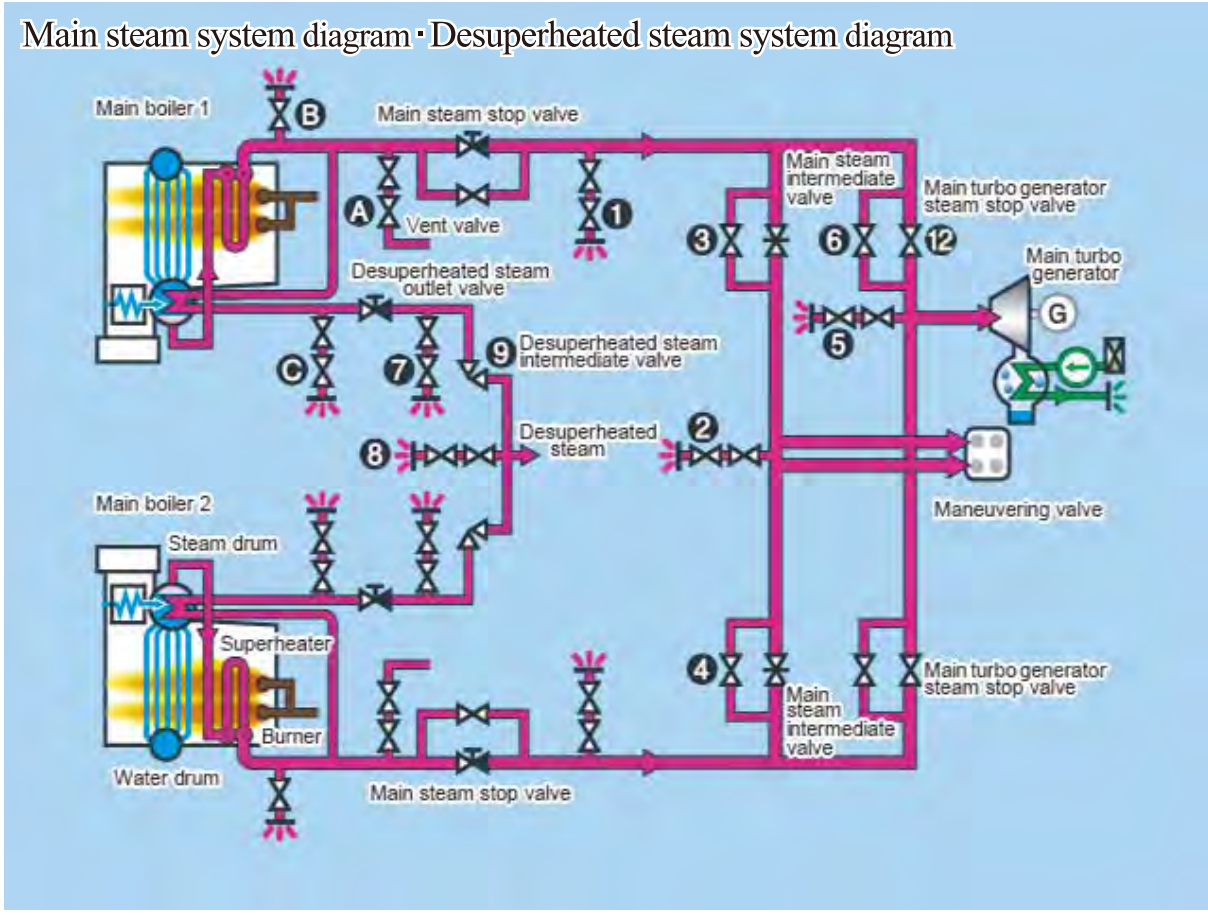
- Confirm that gland exhaust fan is running
- Open gland exhaust stop valve
- Open gland steam-related valves
- Discharge drain
- Set pressure contoller at 0.02 MPa

Start main vacuum pump:

- Open pertinent valves
- Start main vacuum pump
- Stop main vacuum pump when main condenser's vacuum has reached -46 kPa
- Keep main condenser's vacuum within -36 ~ -46 kPa by starting/stopping main vacuum pump accordingly.

Supply warming-up steam:

- Open warming-up steam intermediate valve
- Discharge drain
- Open ahead and astern warming-up steam inlet valves
- Standards to judge completion of the main turbine warming-up:
  *Difference in temperatures between inner and outer surfaces of the high-pressure turbine casing
  *Temperature of low-pressure turbine exhaust space
  *Heat expansion of the high-pressure and low-pressure turbine casings



Warm-up steam piping:

- Slightly open drain valve at outlet of main steam stop valve on the lay-up boiler ❶
- Slightly open drain valve at outlet of desuperheated steam stop valve ❼
- Open desuperheated steam intermediate valve ❾
- Slightly open drain valve on main steam line ❷
- Open main steam intermediate valve's by-pass valves ❸❹
- Slightly open drain valve of main turbo generator stop valve ❺
- Open by-pass valve of main turbo generator stop valve ❻

3. Trial Run Preparation

Put both boilers into parallel operation:

- Set up boiler feed water system on the lay-up boiler
- Replace burners
- Steam-related valves:
  - Open main steam stop valve
  - Close superheater final stage drain valve Ⓑ
  - Close main steam stop valve outlet drain valve ❶
  - Open desuperheated steam stop valve
  - Close main turbo generator stop valve's by-pass valve ❻
  - Close main turbo generator stop valve's drain valve ❺
  - Open main turbo generator stop valve ⓬
  - Close desuperheated steam stop valve outlet drain valve ❼
  - Close desuperheater outlet drain valve Ⓒ
  - Close superheater vent valve Ⓐ

Stop warming-up steam:

- Close warming-up steam intermediate valve
- Close ahead and astern warming-up steam inlet valves

Increase main condenser vacuum:

- Start continuous running of the main vacuum pump

Open main steam intermediate valve:

- Open main steam intermediate valve
- Close main steam intermediate valve's by-pass valves ❸❹
- Close main steam line drain valve ❷

Stop main engine turning:

- Stop main engine turbine turning and disengage the turning gear

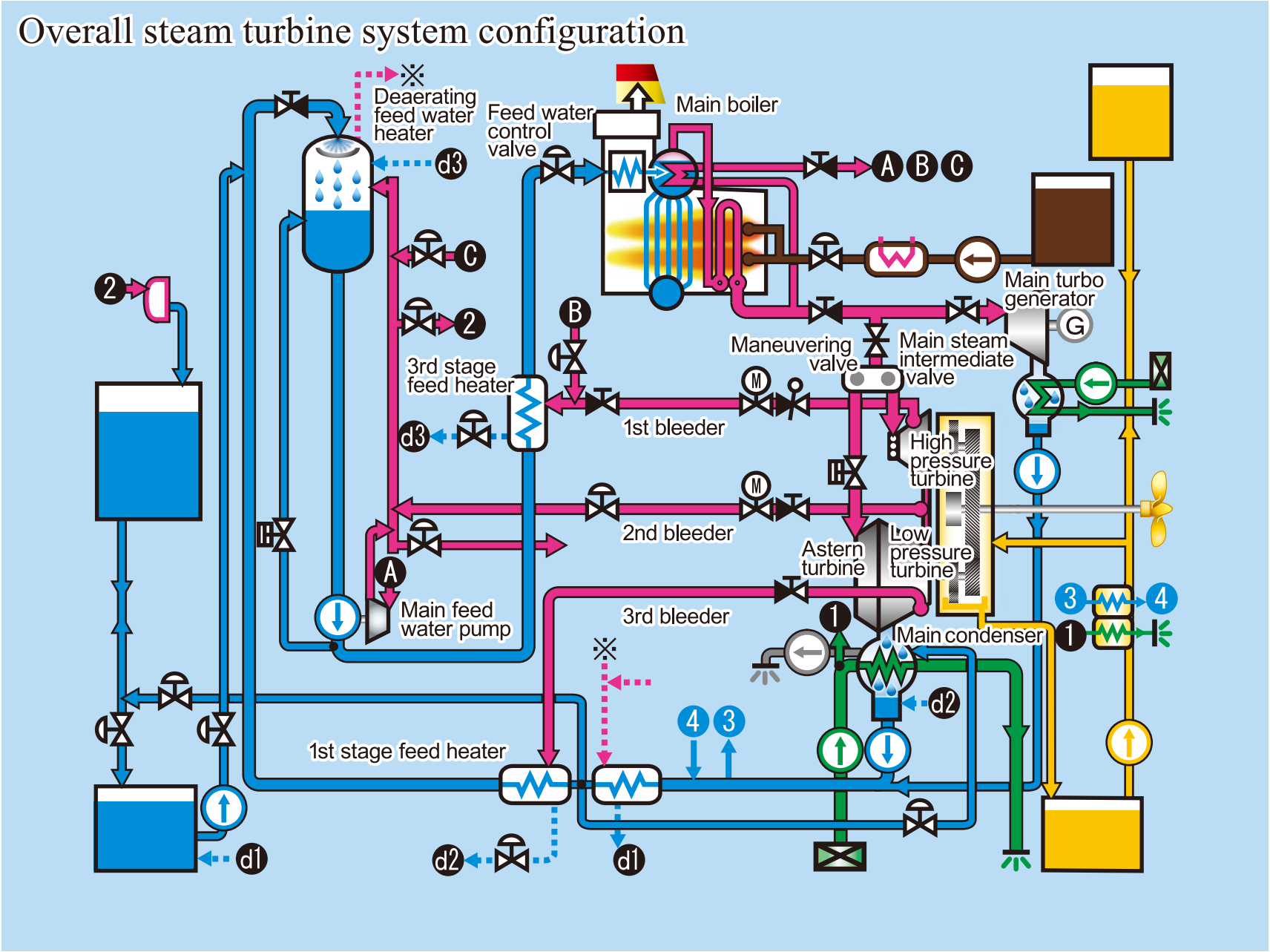
Start main engine spinning:

- Reset control oil pressure
- Start auto spinning

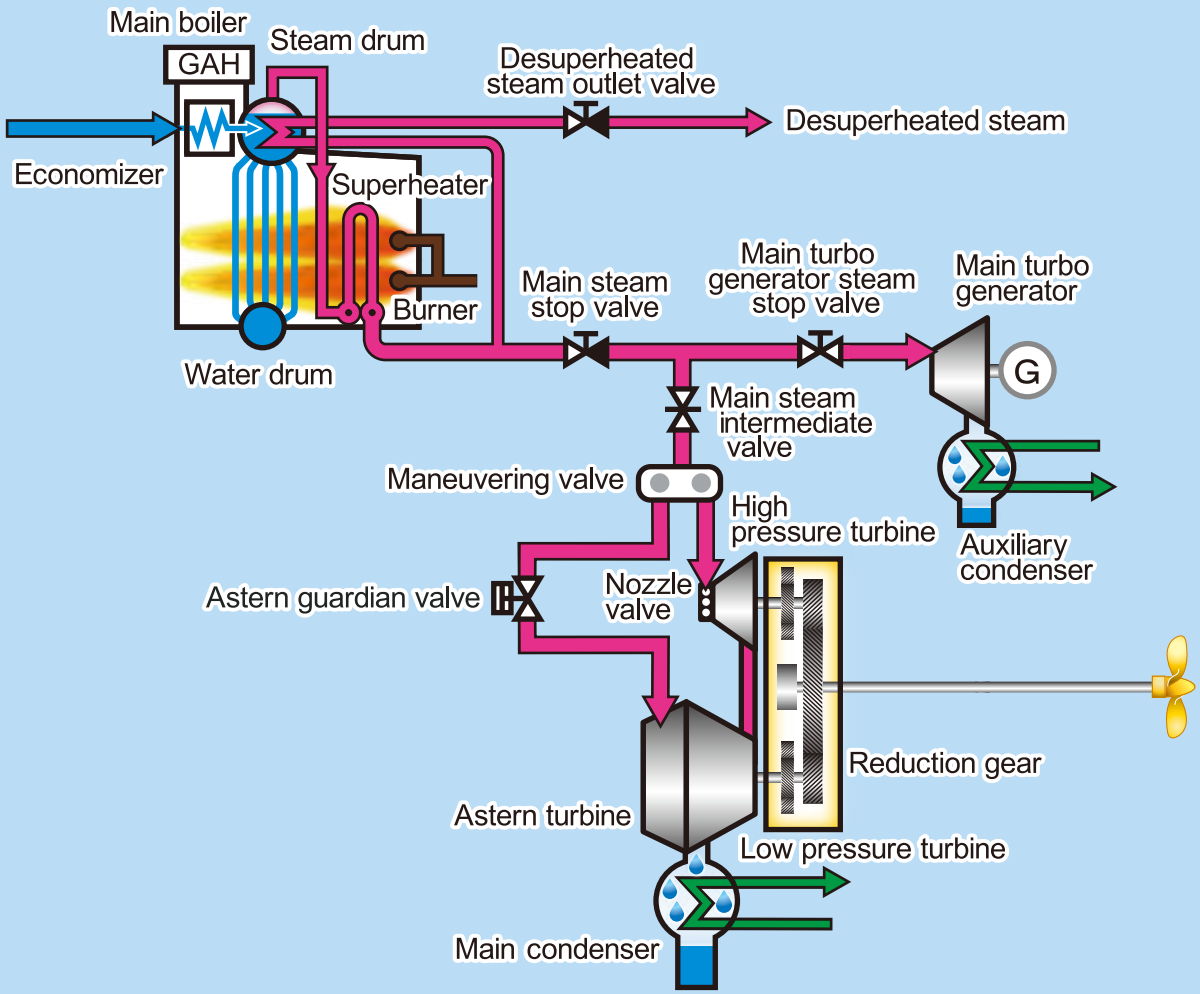
Trial run:

- Trial run in lever control mode from the control room
- Trial run in direct switch control mode from the control room
- Trial run by the emergency maneuvering handle at the main engine local control stand

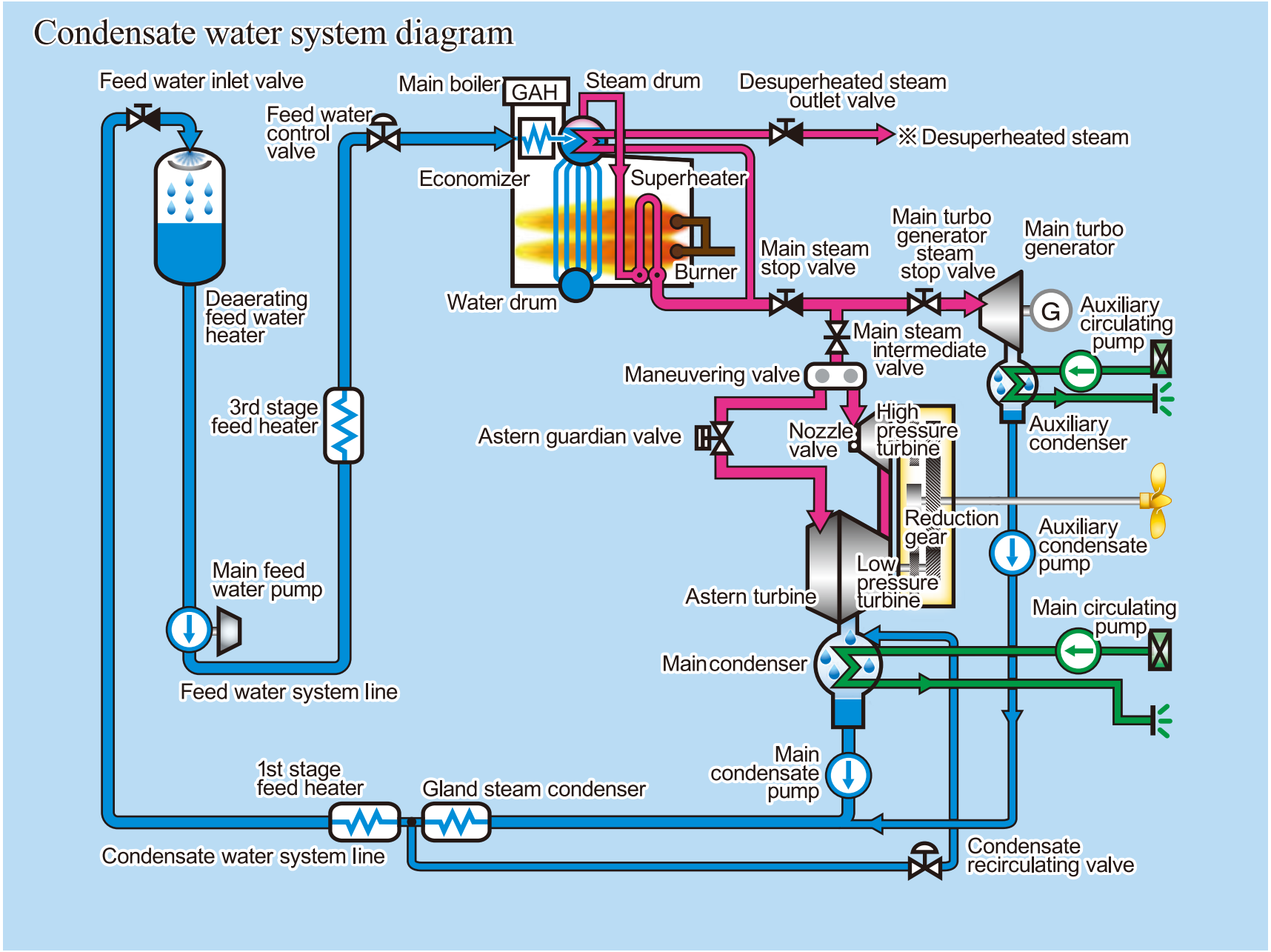
Overall steam turbine system configuration



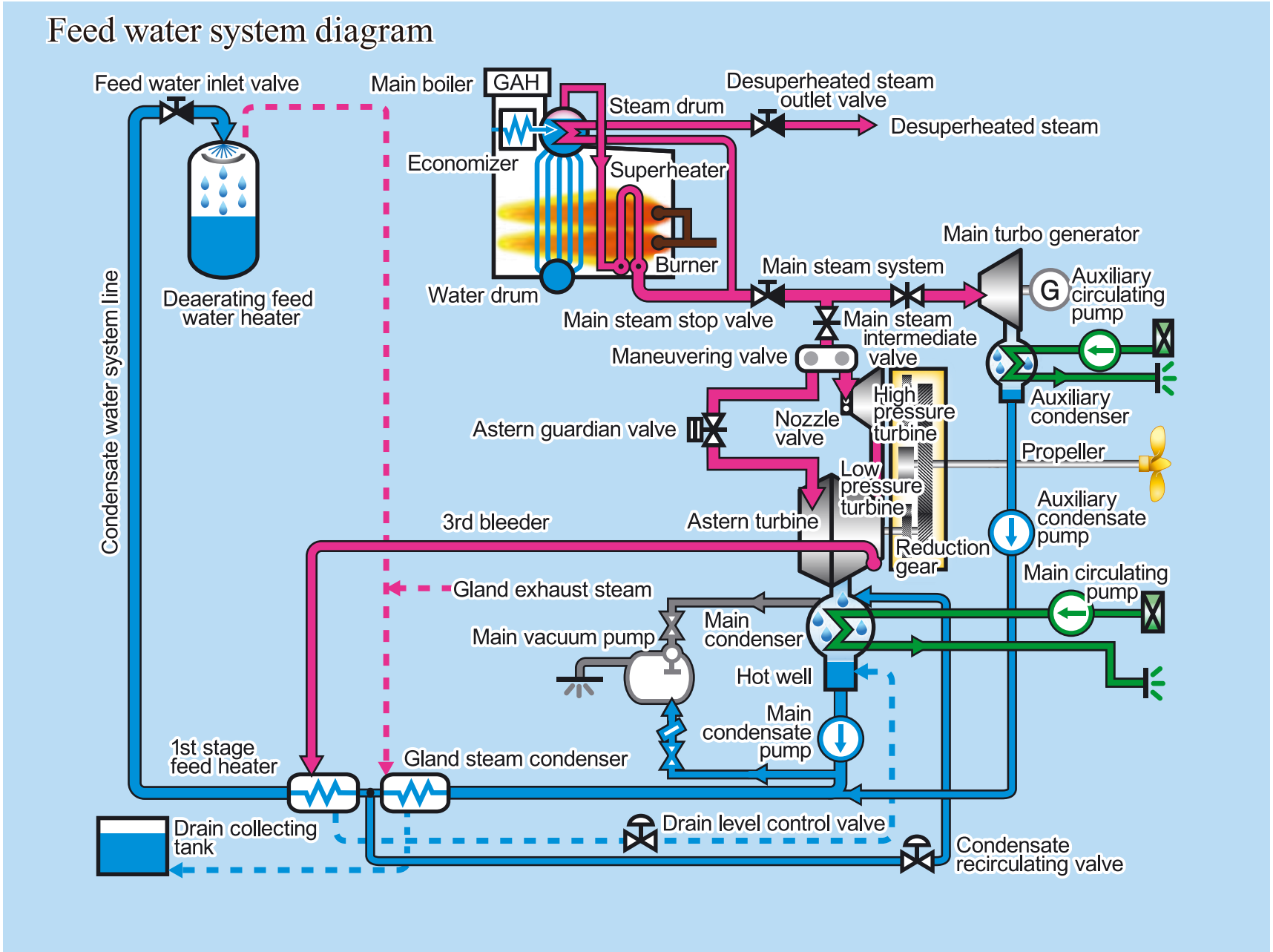
Main steam system diagram



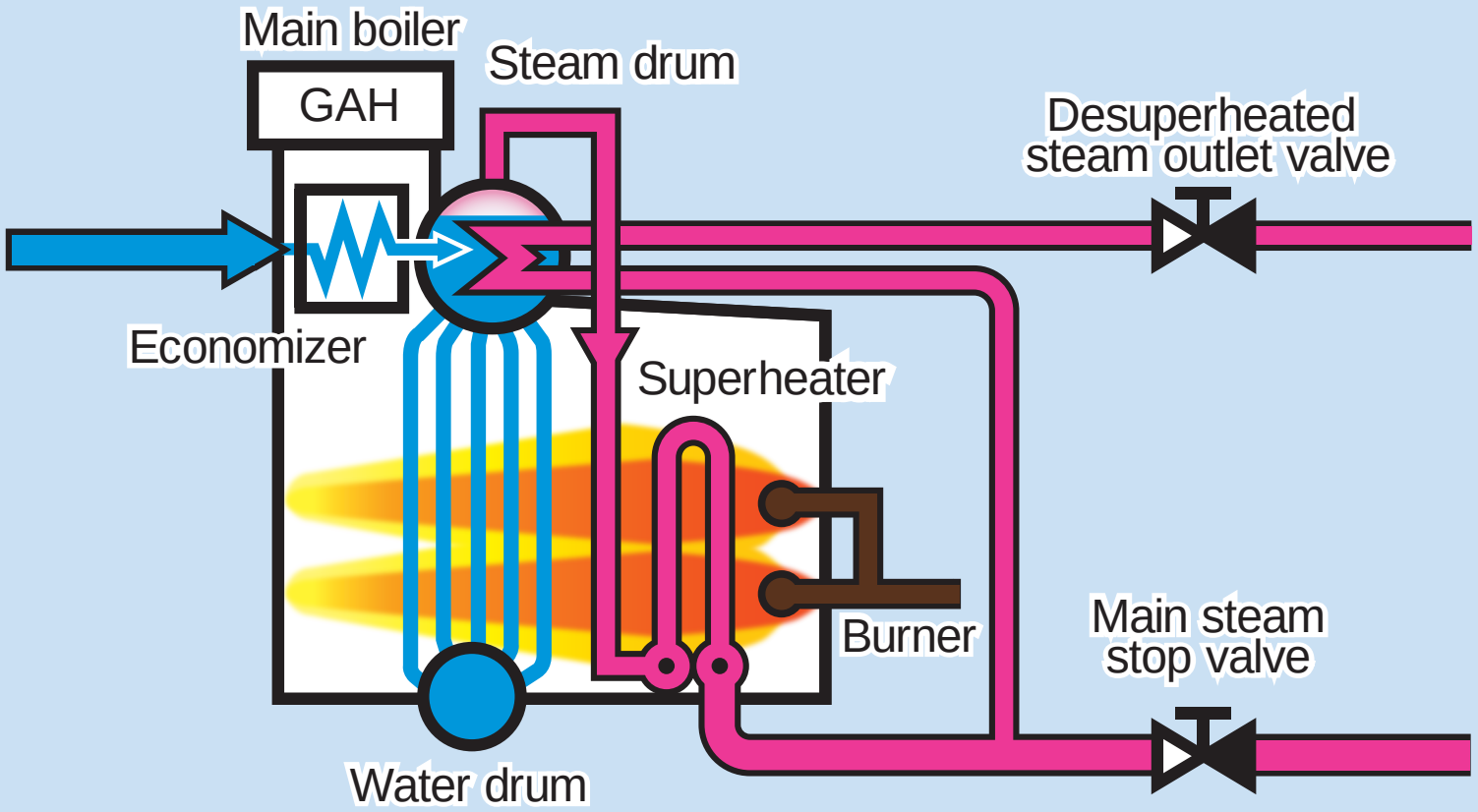
Condensate water system diagram



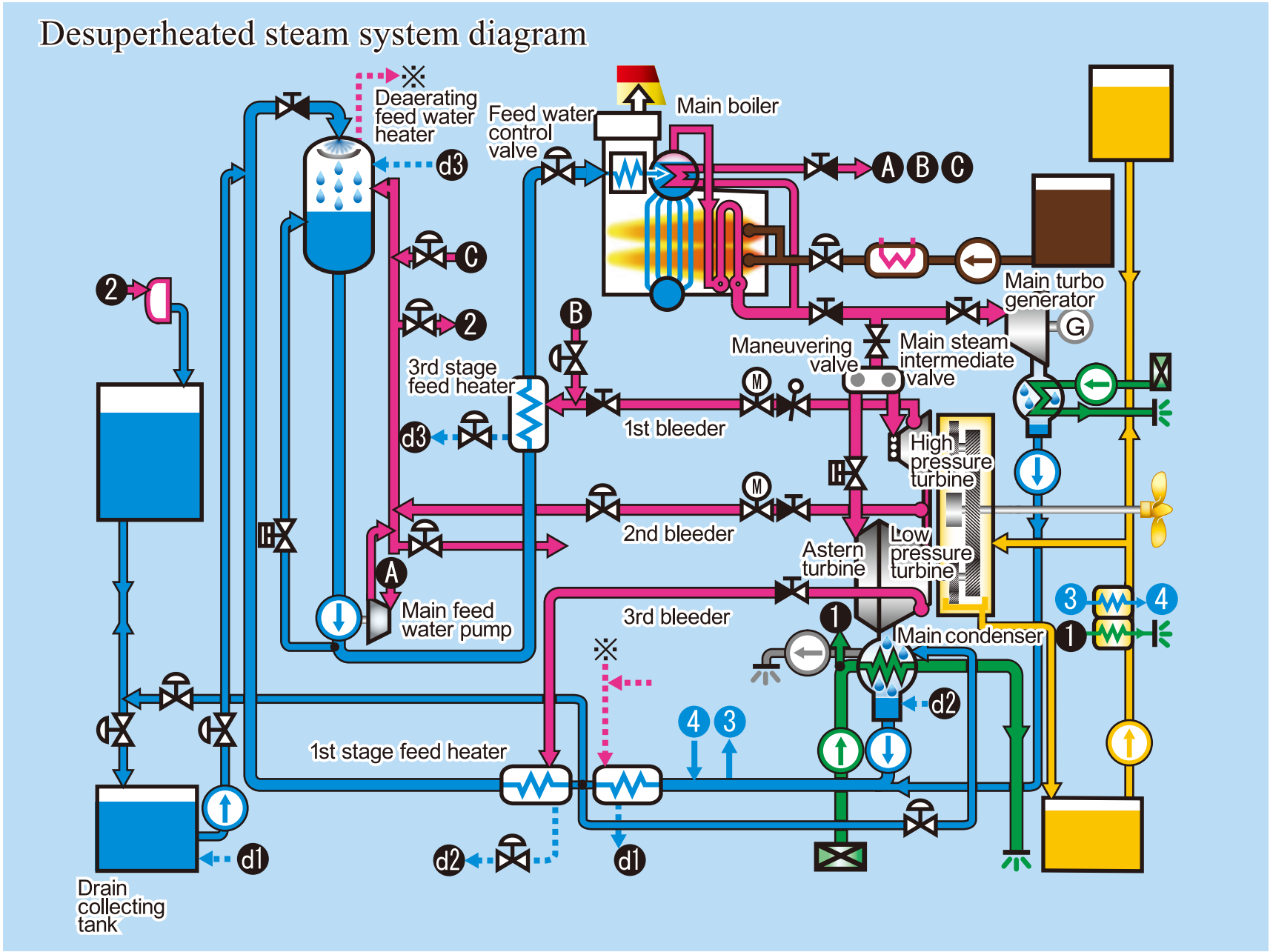
Feed water system diagram



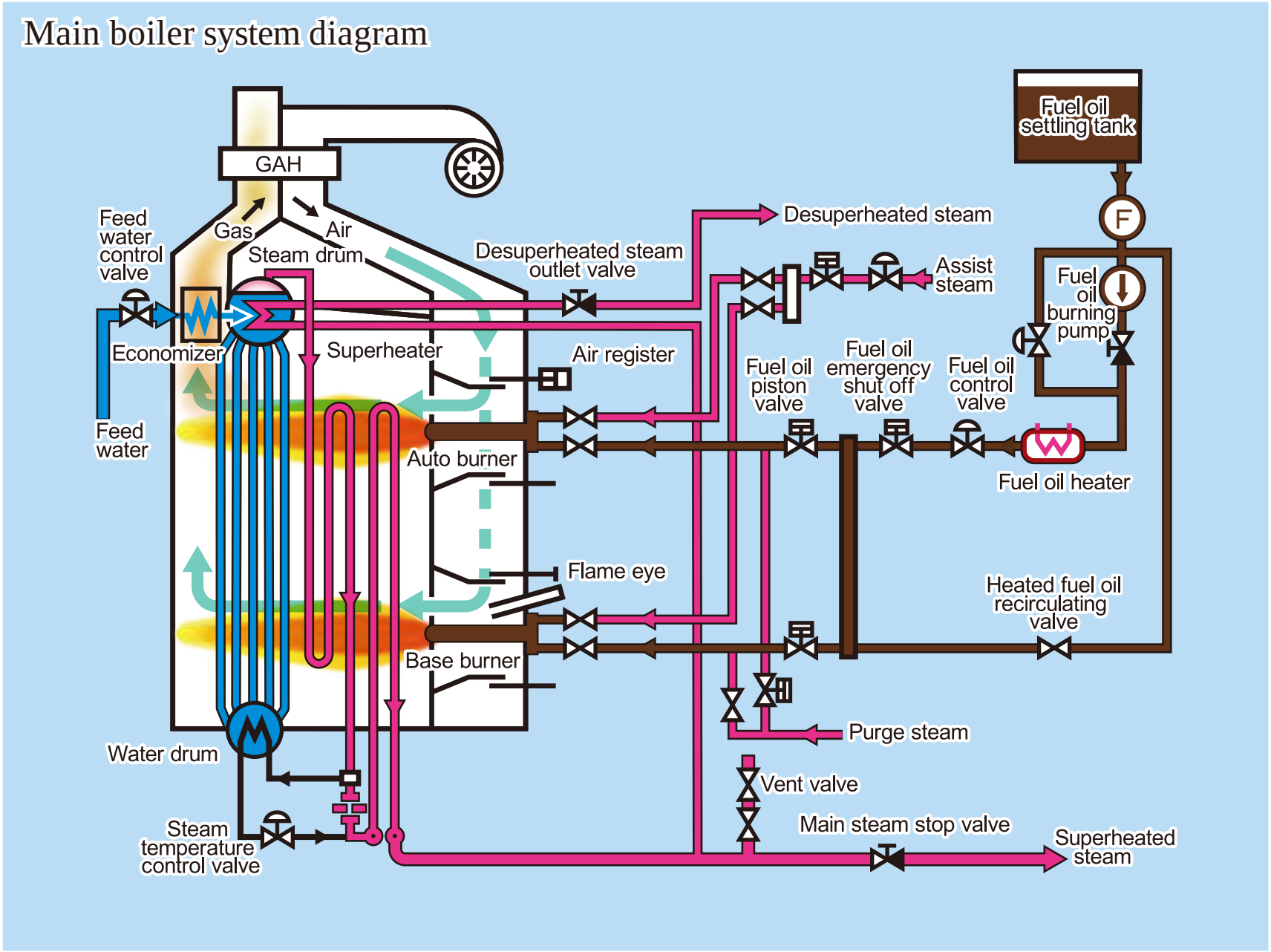
Desuperheated steam system diagram



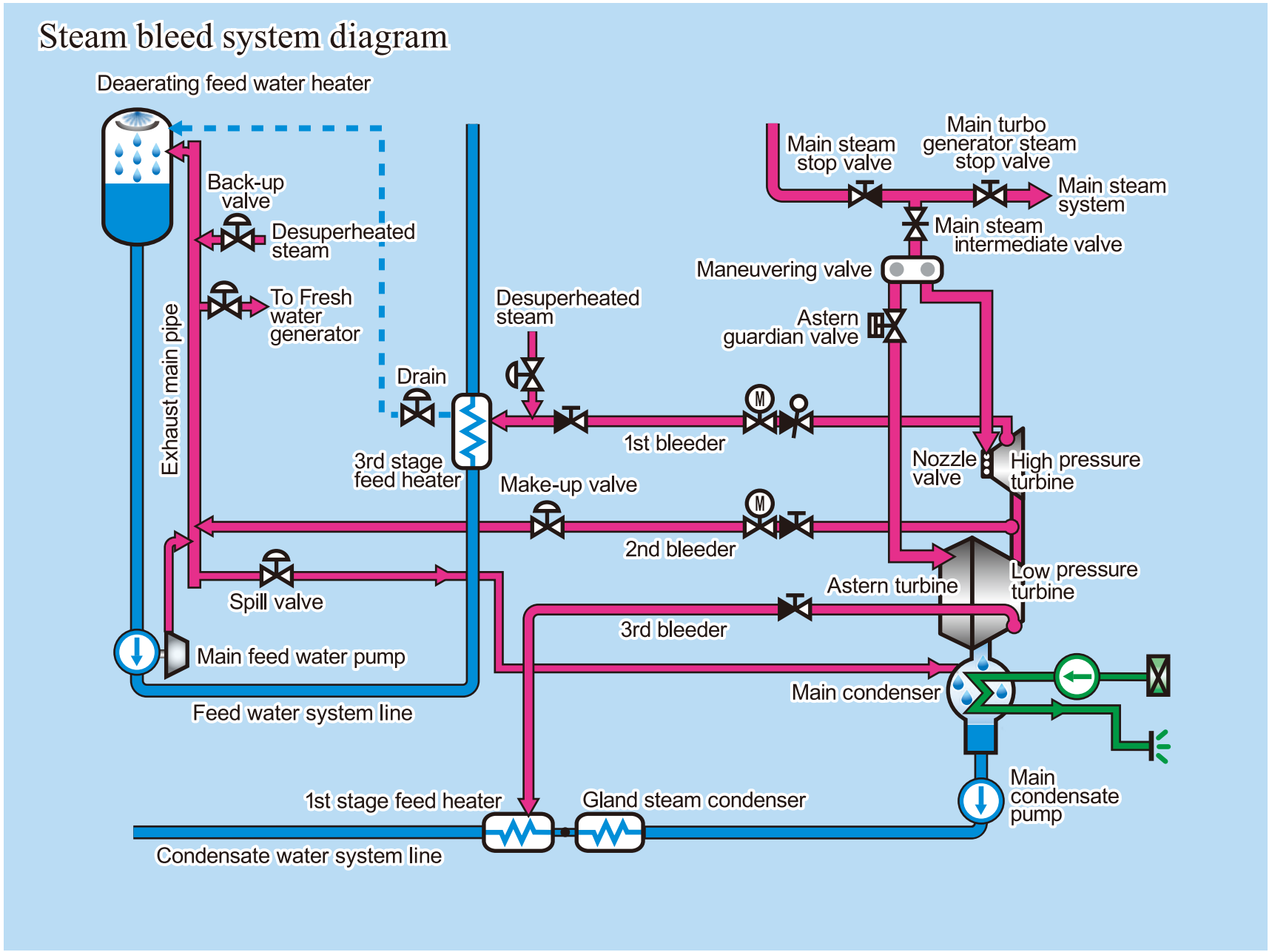
Desuperheated steam system diagram



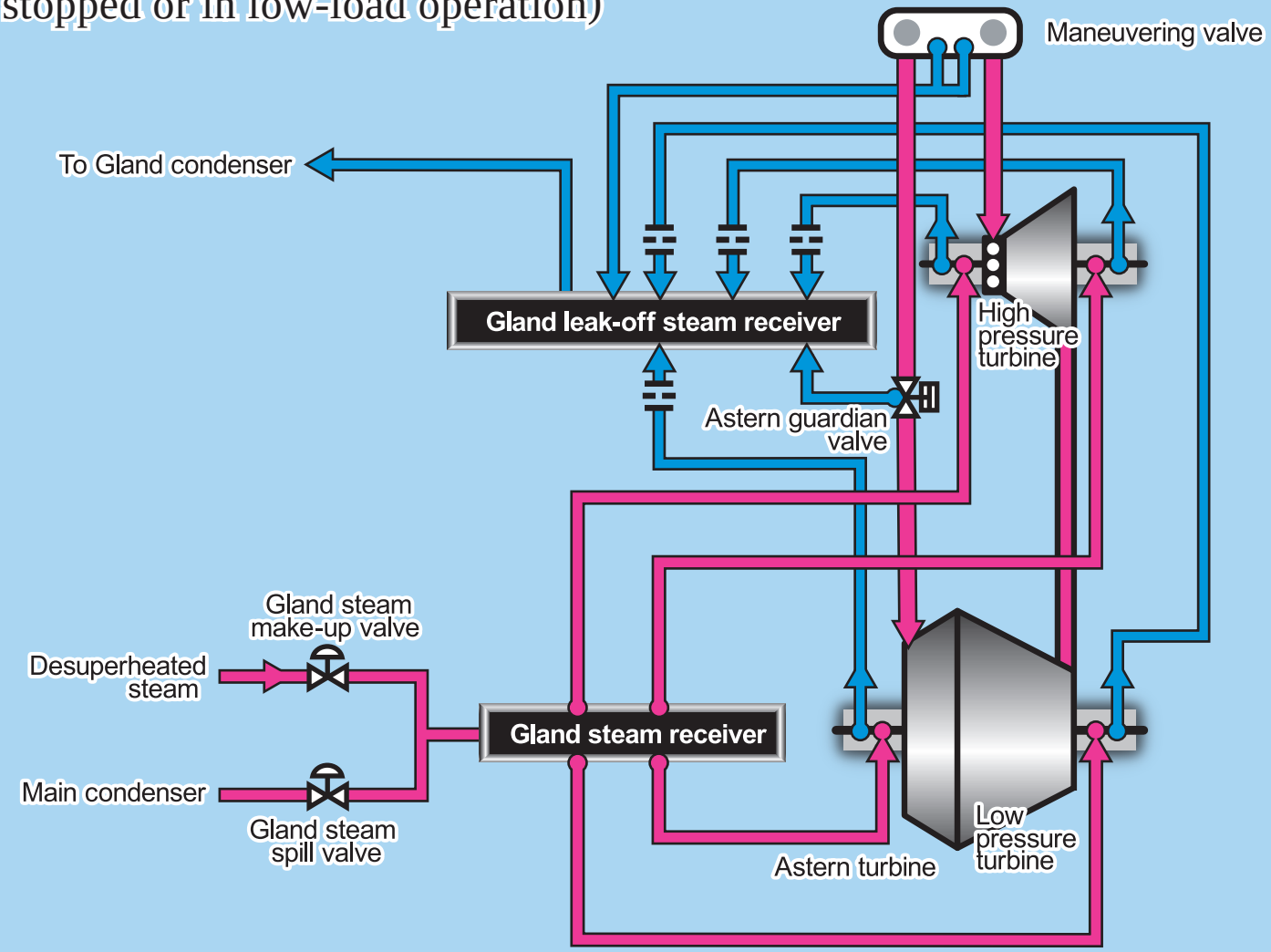
Main boiler system diagram



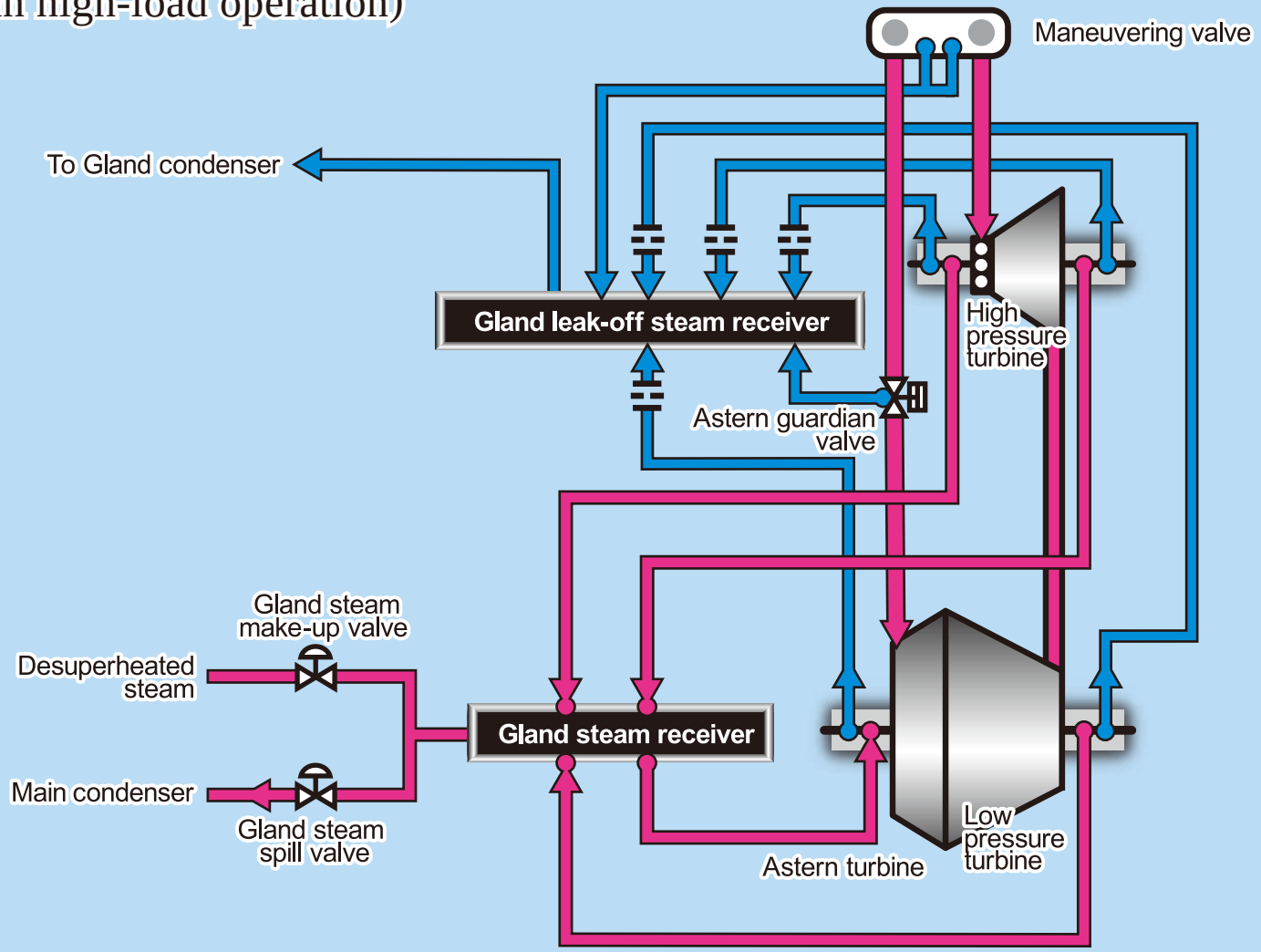
Steam bleed system diagram



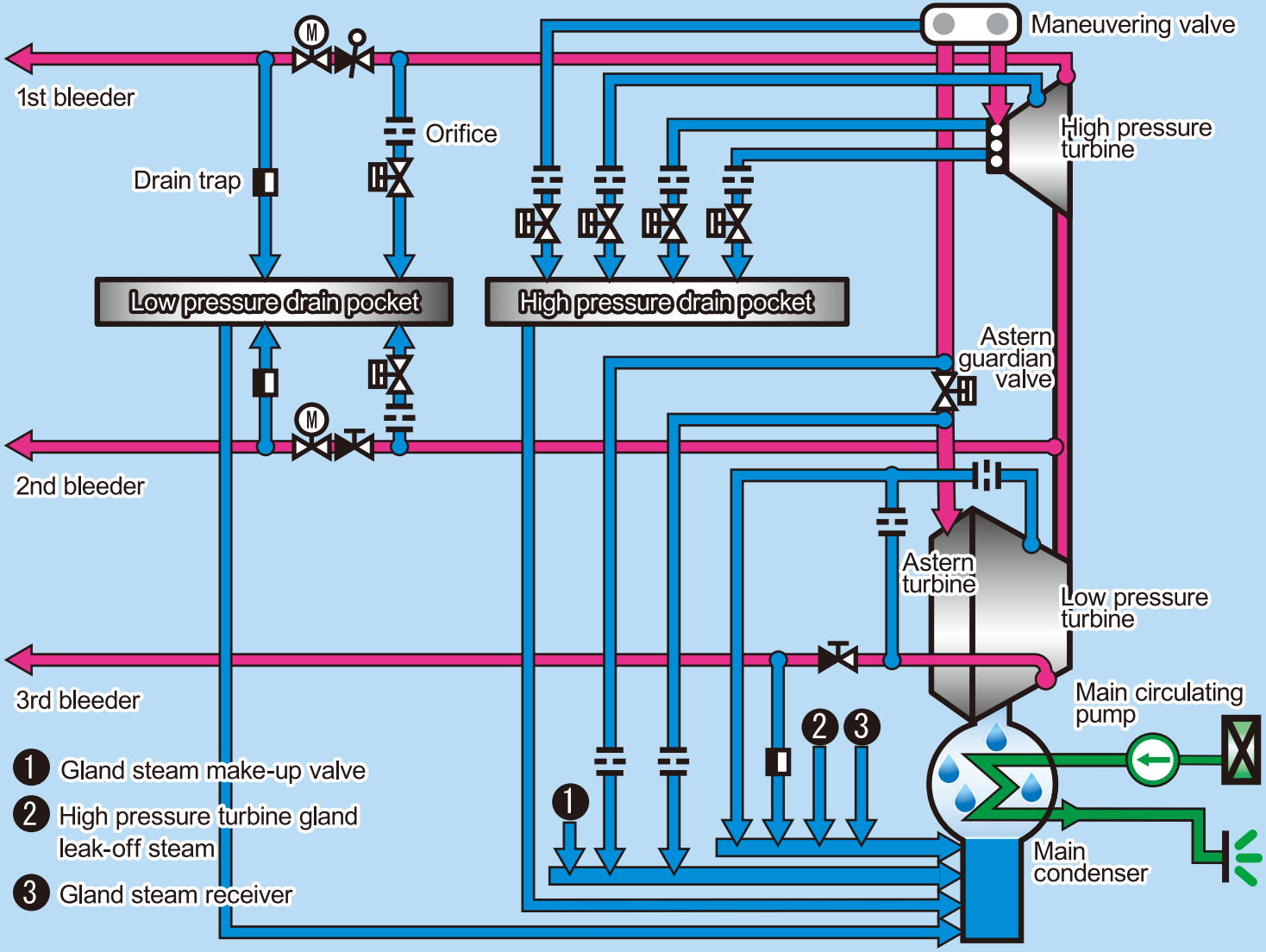
Gland steam system diagram (when stopped or in low-load operation)



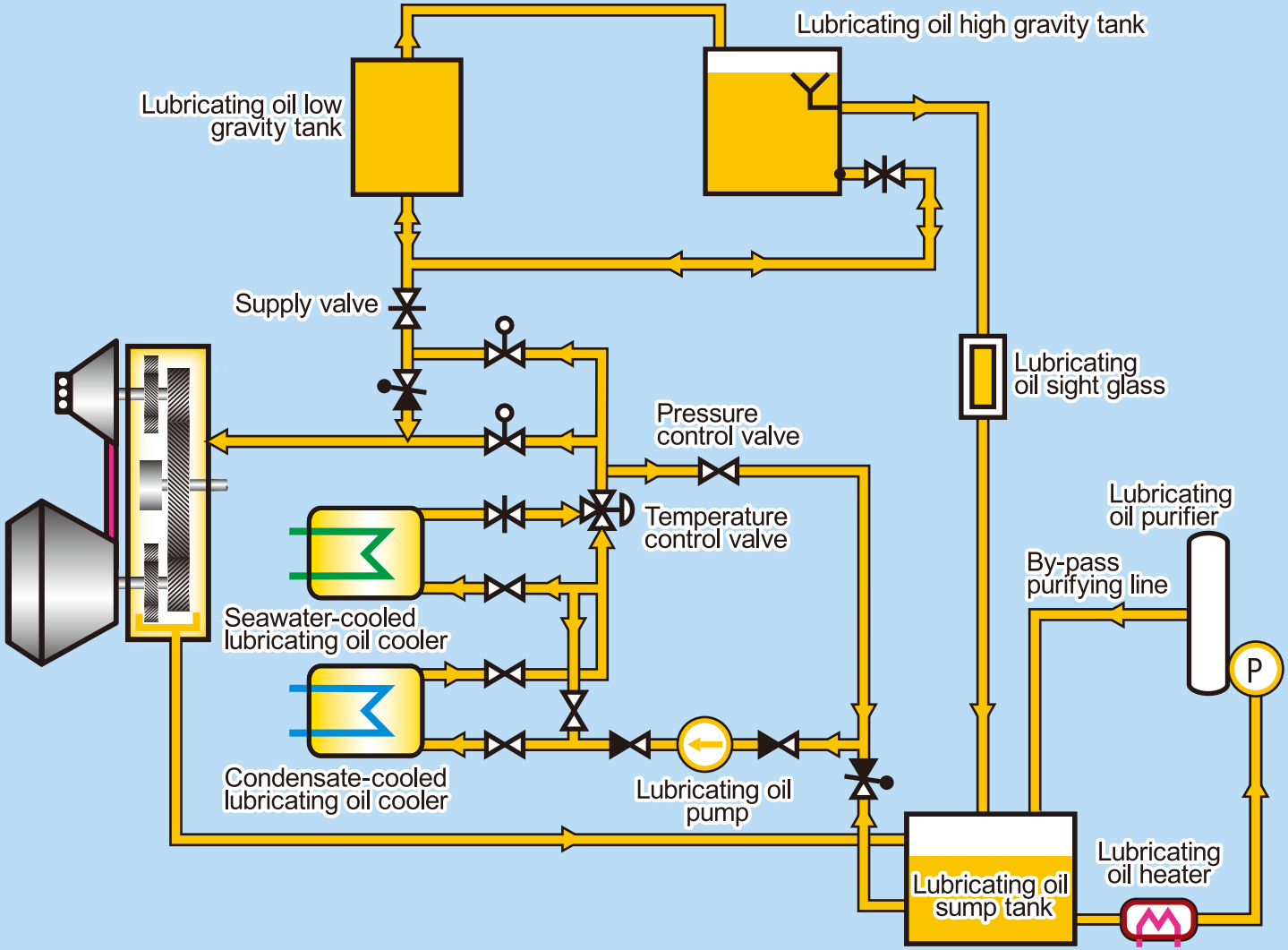
Gland steam system diagram (when in high-load operation)



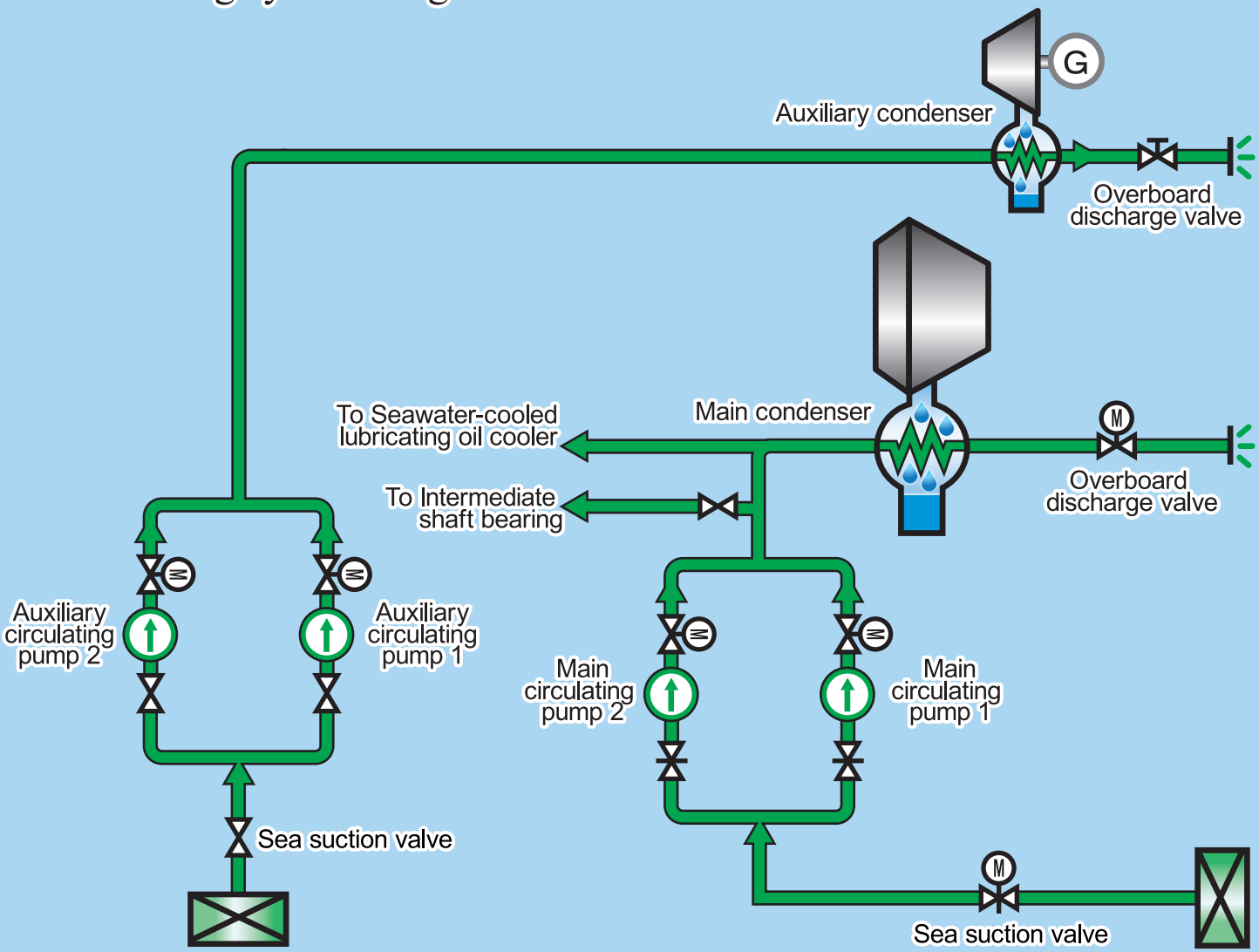
Drain system diagram

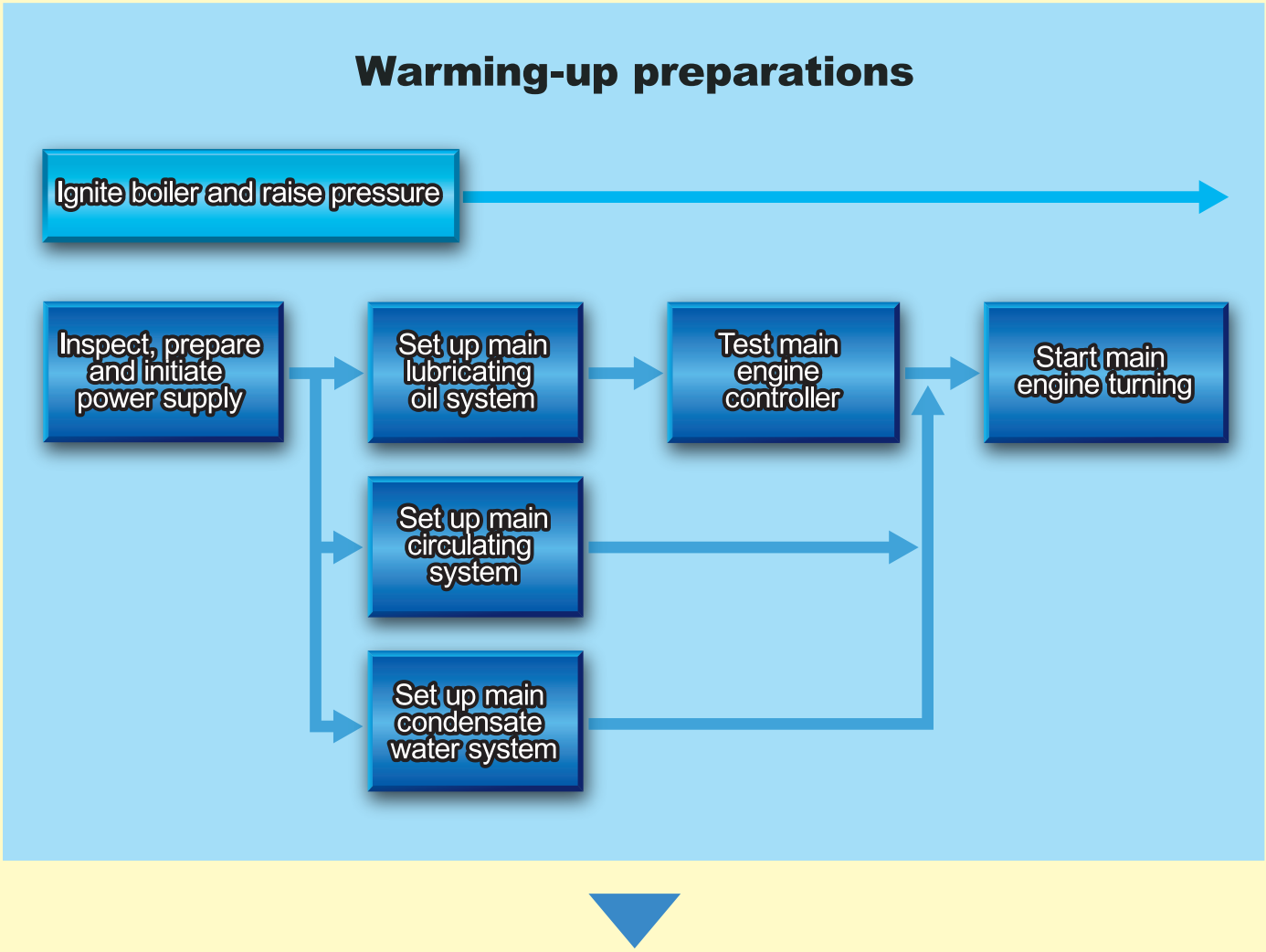


Main lubricating oil system diagram



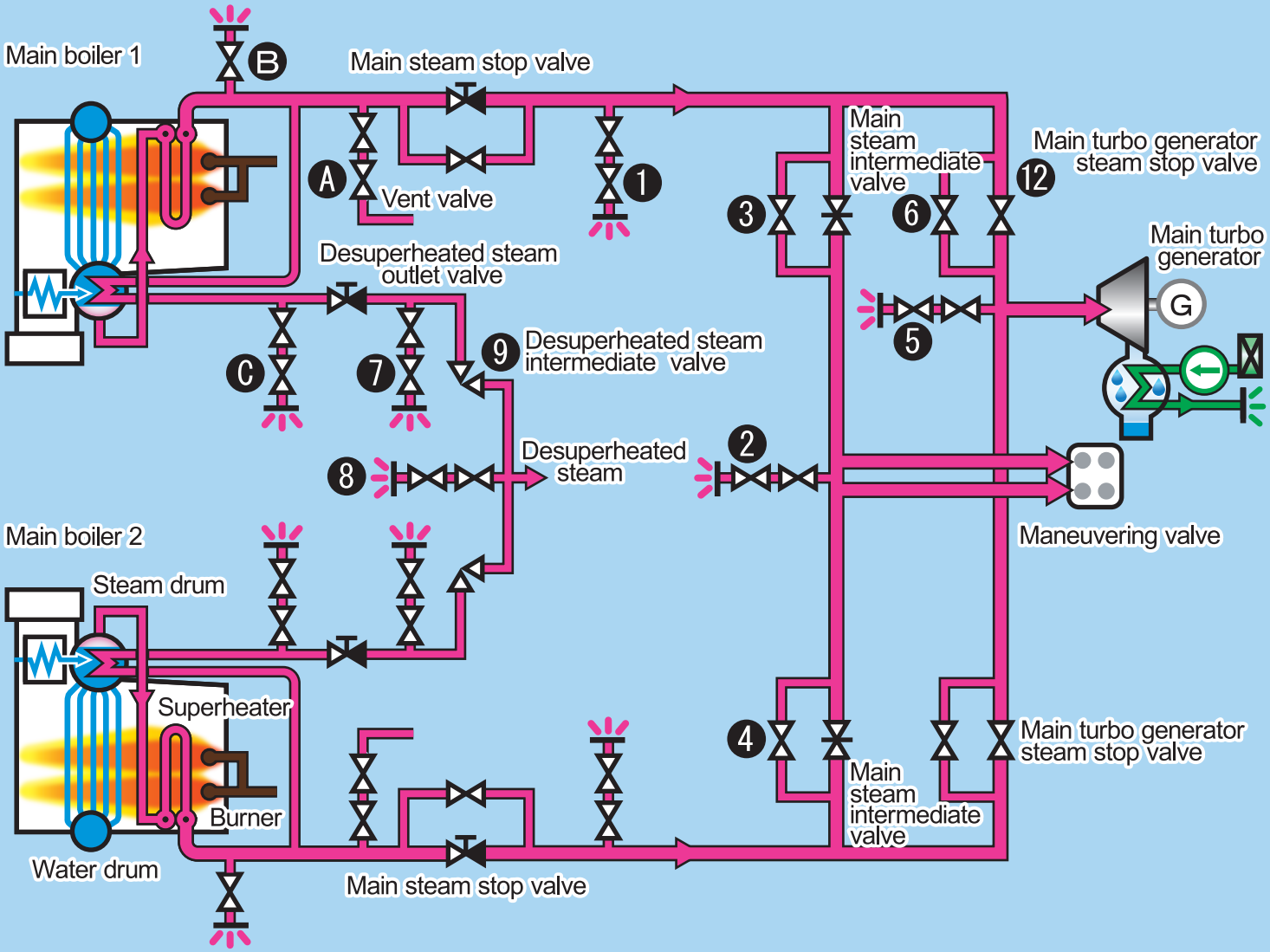
Main circulating system diagram

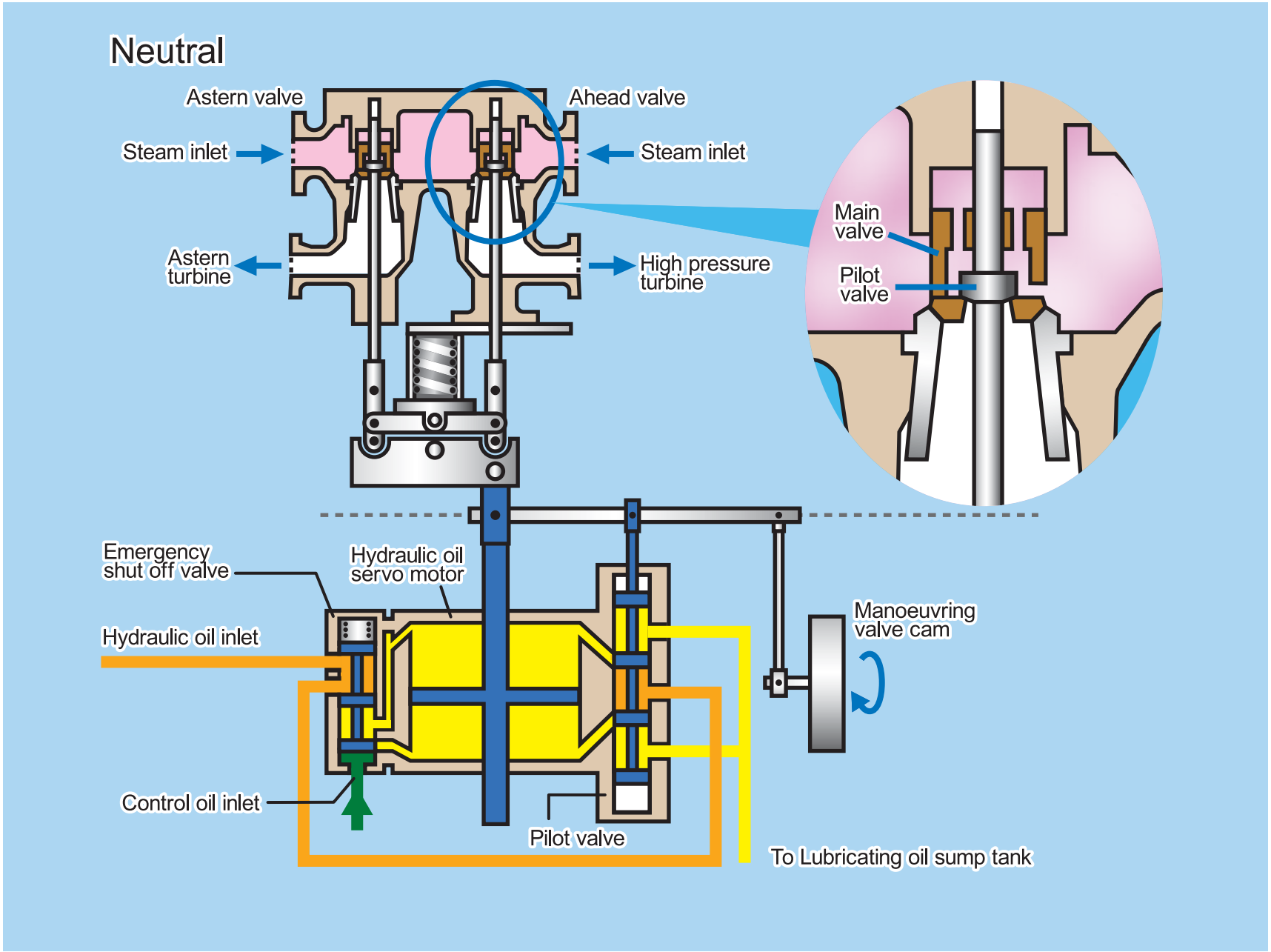


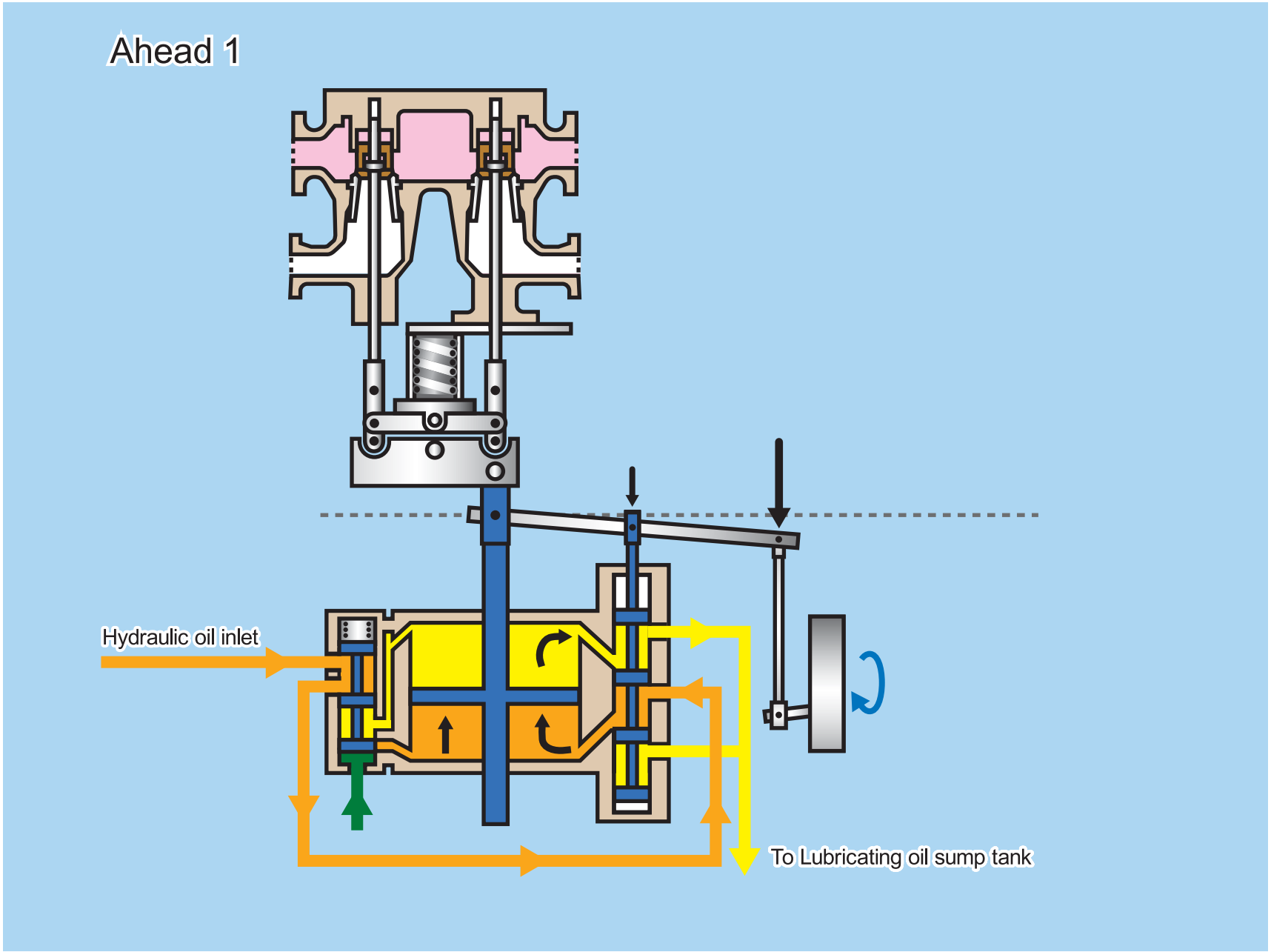

Warming-up preparations
Ignite boiler and raise pressure
Inspect, prepare and initiate power supply
Set up main lubricating oil system
Test main engine controller
Start main engine turning
Set up main circulating system
Set up main condensate water system

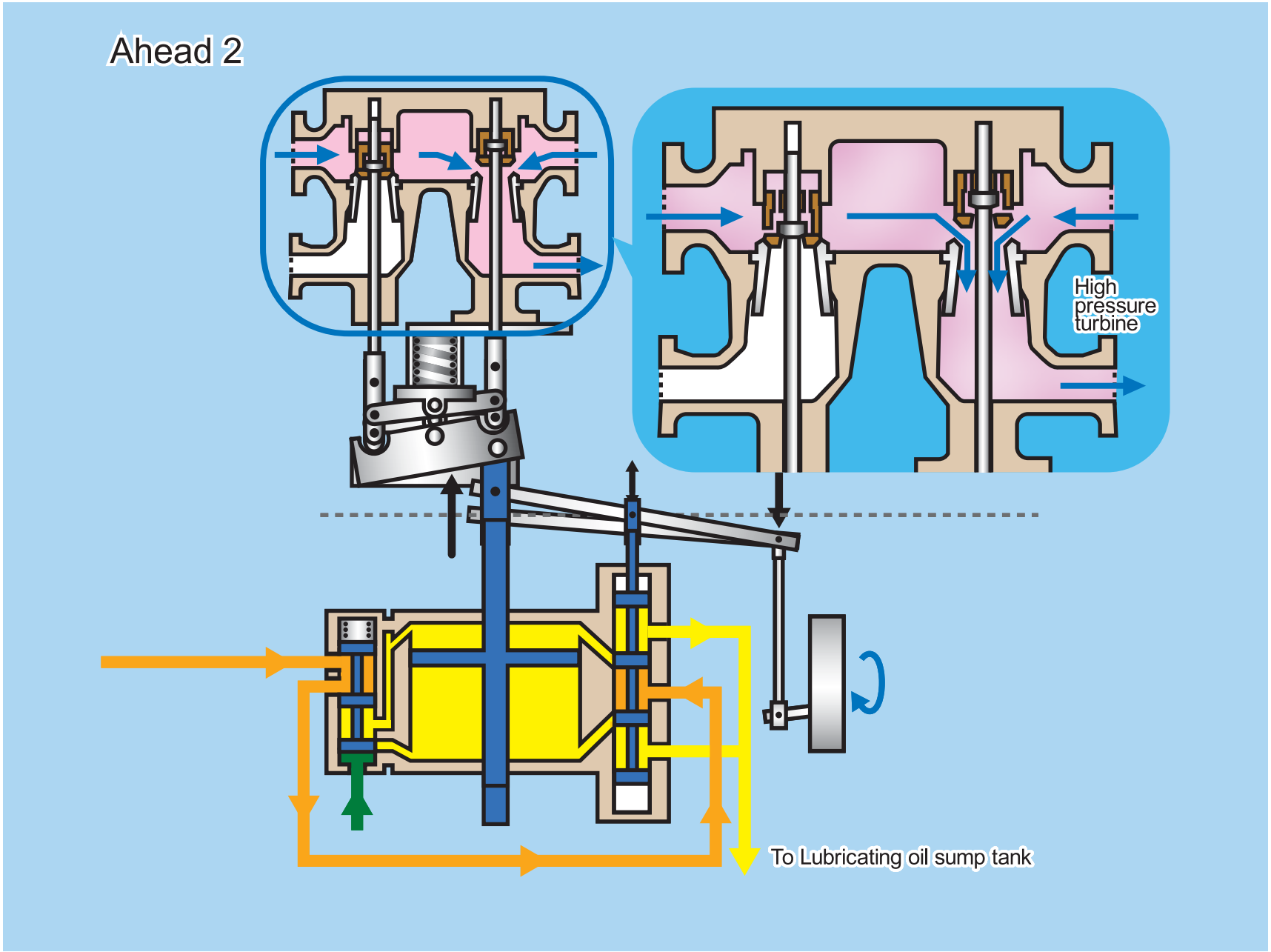

Warming-up operations
Warm-up main steam pipe
Supply gland steam
Start main vacuum pump
Supply warming-up steam
Warming-up
Trial operation preparations
Operations common to boiler
Stop warming-up steam
Increase main condenser vacuum
Open main steam intermediate valve
Stop main engine turning
Start main engine spinning
Trial operation

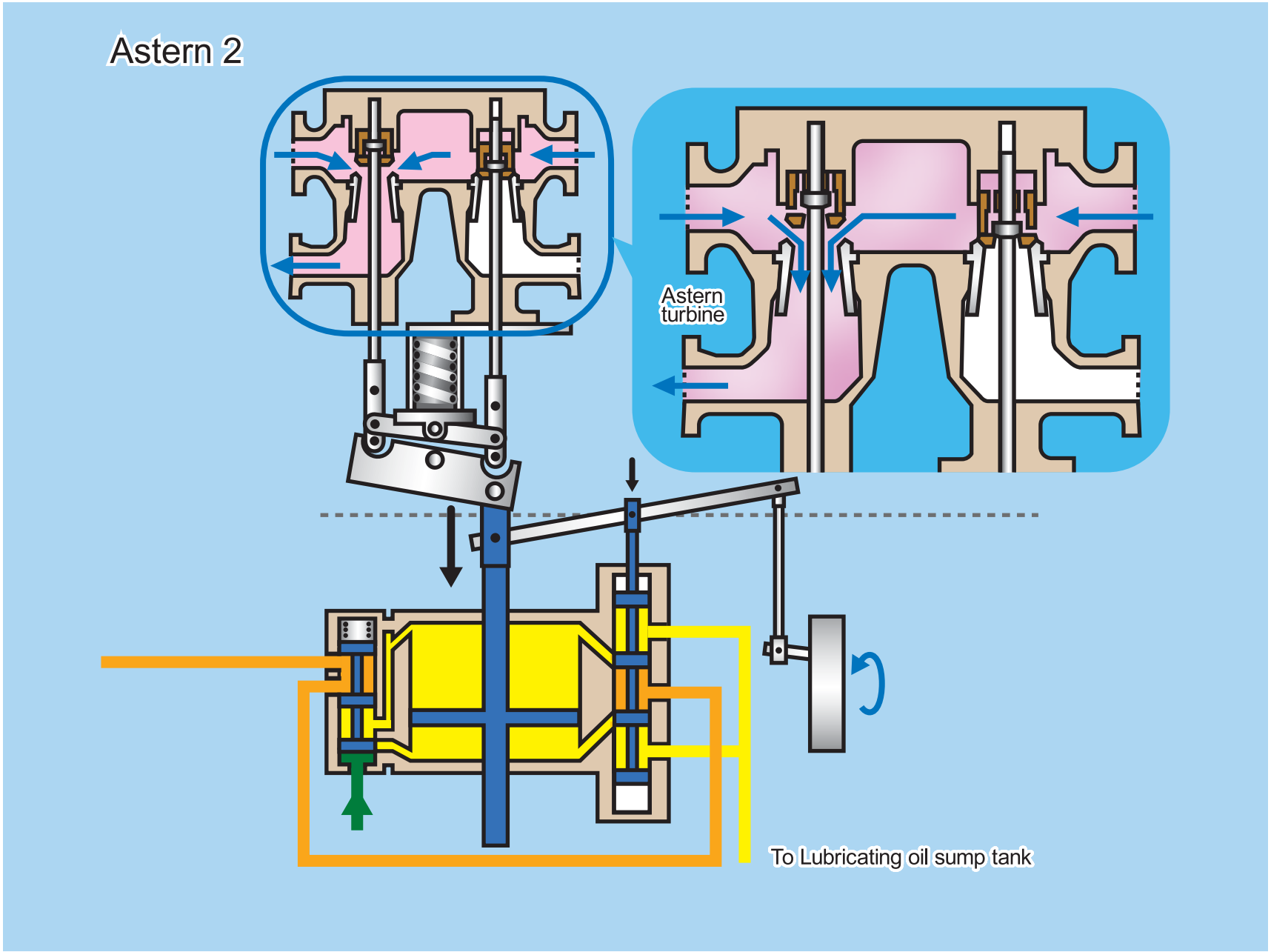
Main steam system diagram·Desuperheated steam system diagram




Neutral
Astern valve
Ahead valve
Steam inlet
Steam inlet
Astern turbine
High pressure turbine
Main valve
Pilot valve
Emergency shut off valve
Hydraulic oil servo motor
Hydraulic oil inlet
Manoeuvring valve cam
Control oil inlet
Pilot valve
To Lubricating oil sump tank


Ahead 1
Hydraulic oil inlet
To Lubricating oil sump tank


Ahead 2
High pressure turbine
To Lubricating oil sump tank


Astern 2
Astern turbine
To Lubricating oil sump tank