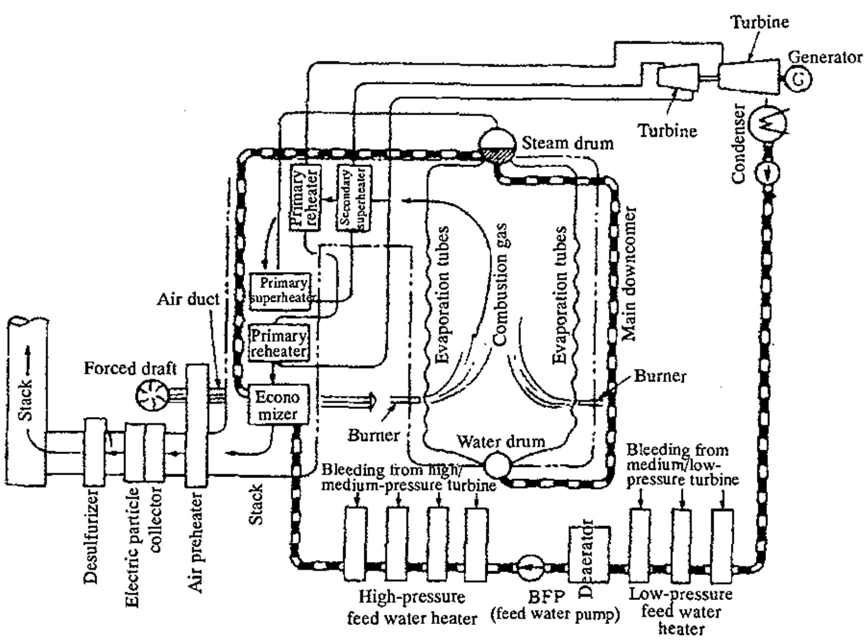
Category				Document No.BO6
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO6
	Paragraph	2	Generating Facilities (Thermal)	
	Clause			
Title	Flows of Air and Combustion Gas			

The air pressurized in the forced draft flows through the air duct into the air preheater where it is preheated by flue gas. Then, the preheated air passes through the air duct and is sent to the air damper on the combustion burners provided in several stages where it is mixed with the fuel, catches fire and changes into combustion gas. After having provided the heat to the boiler water in the furnace cooling pipes (evaporation tubes) for becoming a saturated steam, the combustion gas flows in the direction marked with arrows. The combustion gas passes through the secondary superheater, the secondary reheater, the primary superheater, the primary reheater, the economizer and the air preheater which are provided in the gas duct to enhance the thermal efficiency, and passes (via an induced draft fan in a coal burning thermal power station) through a particle collector and a desulfurizer for removing air pollutants before being discharged from the stack.



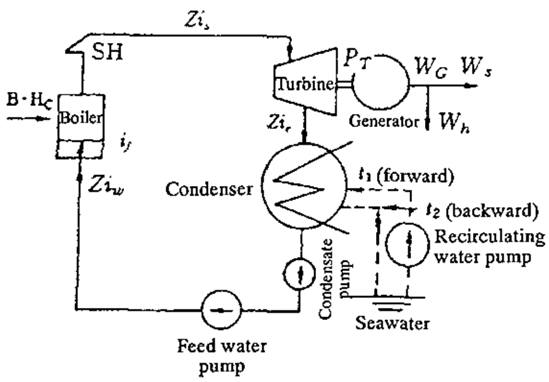
Flows of air and combustion gas

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.BO7-1
	Paragraph	2	Generating Facilities (Thermal)	
	Clause			
Title	Thermal Efficiency and Its Improvements (1)			

Thermal Efficiency

Various efficiencies should be determined in order to operate a thermal power station in an economical and efficient manner. The following subsections will describe the methods for determining these efficiencies.



Z : Flow rate for main steam [kg/h]
i_s : Steam enthalpy at the outlet of the superheater [kJ/kg]
i_e : Steam enthalpy at the outlet of the turbine final stage [kJ/kg]
i_w : Feed water enthalpy [kJ/kg]
i_f : Feed water enthalpy at the outlet of the economizer [kJ/kg]
P_T : Turbine output [kW]
W_G : Generated electric energy [kWh]
W_h : Station electric energy [kWh]
W_S : Transmitted electric energy [kWh]
η_c : Heat cycle efficiency
η_t : Turbine efficiency
η_g : Generator efficiency
η_{tg} ($=\eta_t \cdot \eta_g$): Total efficiency of turbine and generator
B : Fuel consumption [kg/h], [kl/h], [N·m³/h]
H_c : Calorific value [kJ/kg], [kJ/kl], [kJ/N·m³]
t_1, t_2: Seawater temperature ($t_1 < t_2$)
SH : Superheater

Thermal efficiencies for thermal power station

(1) Boiler efficiency η_b

$$\eta_b = \frac{\text{Quantity of heat fed to the turbine}}{\text{Quantity of heat fed to the boiler}} = \frac{\text{Steam energy [kJ/h]}}{\text{Combustion energy [kJ/h]}}$$
$$= \frac{Z\,(i_s - i_w)}{B \cdot H_C} \times 100\ [\%] \qquad (1\text{-}10)$$

(2) Turbine chamber efficiency η_T

When theoretical work (input) is given as quantity of heat produced during an adiabatic expansion of steam from the turbine inlet pressure to the condenser vacuum, with Pt being the turbine output at the turbine shaft end,

$$\eta_T = \frac{\text{Turbine output as quantity of heat}}{\text{Quantity of heat absorbed in the boiler}} = \frac{3600P_T}{Z(i_s - i_w)}$$
$$= \frac{i_s - i_\ell}{i_s - i_w} \times \frac{3600P_T}{Z(i_s - i_\ell)} = \eta_c \eta_t\ (\times 100)\ [\%] \qquad \text{..............................(1-11)}$$

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO7-2
	Paragraph	2	Generating Facilities (Thermal)	
	Clause			
Title	Thermal Efficiency and Its Improvements (2)			

(3) Turbine steam consumption ω

$$\omega = \frac{Quantity\ of\ steam}{Generated\ electric\ energy} = \frac{Z}{W_G} = \frac{Z}{P_T \times \eta_g} = \frac{3\,600}{\eta_T(i_s - i_w)\eta_g}$$
$$= \frac{3\,600}{\eta_c(i_s - i_w)\eta_t\eta_g} = \frac{3\,600}{(i_s - i_e)\eta_{tg}}\ [\text{kg/kWh}] \quad \text{(1-12)}$$

(4) Generating-end heat consumption S

$$S = \frac{3\,600}{\text{Gross thermal efficiency}\ \eta_p} = \frac{3\,600}{\dfrac{3\,600 W_G}{B \cdot H_c}} = \frac{B \cdot H_c}{W_G}\ [\text{kJ/kWh}] \quad \text{(1-13)}$$

(5) Gross thermal efficiency η_p

$$\eta_p = \frac{\text{Generated electric energy} \times 3600}{\text{Quantity of heat fed to the boiler}} = \frac{3\,600 W_G}{B \cdot H_c} = \eta_b\eta_t\eta_g\ (\times 100)\ [\%] \quad \text{(1-14)}$$

(6) Net thermal efficiency η_s

$$\eta_s = \frac{(\text{Generated electric energy - Station electric energy consumption}) \times 3\,600}{\text{Quantity of heat fed to the boiler}}$$
$$= \frac{(W_G - W_h) \times 3600}{B \cdot H_c} = \frac{3\,600 W_G}{B \cdot H_c}(1 - \frac{W_h}{W_G}) = \eta_p(1 - L)\ (\times 100)[\%] \quad \text{(1-15)}$$

(7) Auxiliary power ratio L

$$L = \frac{\text{Station electric energy consumption}}{\text{Generated electric energy}} = \frac{W_h}{W_G} \times 100\ [\%] \quad \text{(1-16)}$$

Most thermal power stations are based on the rankine cycle. Even in a thermal power station that uses a reheating/regeneration cycle in supercritical-pressure steam conditions, the **gross thermal efficiency η_p** is lower than **41%. Most of the thermal energy is carried away in the seawater when the steam having finished its work in the turbine is changed into water.**

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO8
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause			
Title	Enhancing Thermal Efficiency			

(1) Possible measures

1) Use a reheating/regeneration cycle;

2) Use high-pressure, high-temperature steam;

3) Increase the condenser's degree of vacuum;

4) Recover the remaining heat of the boiler's exhaust gas;

5) Economize the station electric energy.

(2) Equipment for enhancing thermal efficiency

1) Reheating cycle: reheater;

2) Regeneration cycle: feed water heater, gland steam condenser, condensate return tank, number of turbine bleeding stages;

3) High-pressure, high-temperature steam: superheater, high-performance high-pressure feed water pump;

4) Condenser's degree of vacuum: vacuum pump, jellyfish prevention, condenser capillary tube flushing mechanism, backwash valve;

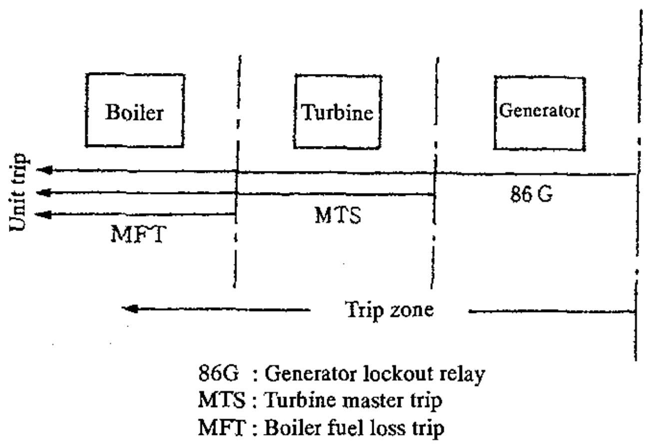
5) Recovery the exhaust gas remaining heat: air preheater (air line), economizer (feed water);

6) Economizing the station electric energy: control of the number of transformer cooling fans depending on the load.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO9
	Paragraph	2	Generating Facilities (Thermal)	
	Clause			
Title	Protective and Safety Device			

A power station is basically protected in the system as shown.



Basic scheme of protection of power station

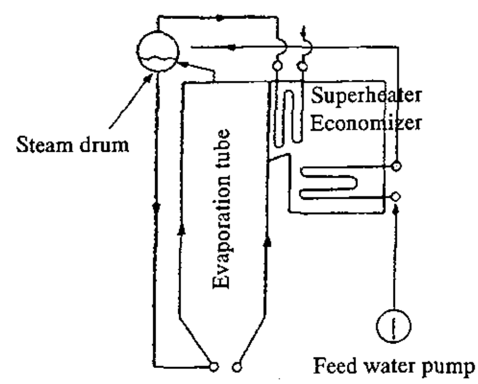
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO10-1**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	**Types of Boilers (1)**			

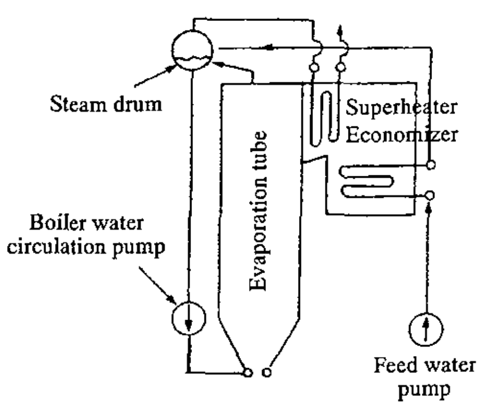
The types of boilers used for electric power generation have a large amount of evaporation and require a high-temperature, high-pressure steam. One of these boilers is the water pipe boiler in which the water in the pipes evaporates under the effect of either the radiation heat of the flames on the outer surface of the pipe or the combustion gas.

The furnace consists of evaporation tubes in which the fuel is burn. Depending on the water circulation system, one of two types of boilers is used: circulation boiler or once-through boiler.

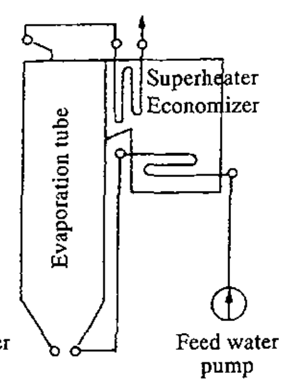
A circulation boiler contains a steam drum. One of the two types of circulation boilers is used: *natural circulation boiler (a) or controlled circulation boiler (b).*



(a) Natural circulation boiler



(b) Controlled circulation boiler



(c) Once-through boiler

Types of boilers

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO10-2
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Types of Boilers (2)			

1. Natural Circulation Boiler (4 to 17 MPa)

This type of boiler is based on the phenomenon of convection of boiling water in evaporation tubes. The water in the upper drum flows down through the main downcomer and enters the lower water drum. The water passes through the evaporation tubes which comprise a furnace, being heated from the bottoms of the pipes. The steam generated during the rise of temperature flows into the drum with the water. The steam is retrieved into the superheater and the water flows down in the down comer pipe for recirculation.

2. Controlled Circulation Boiler (about 17 Ma)

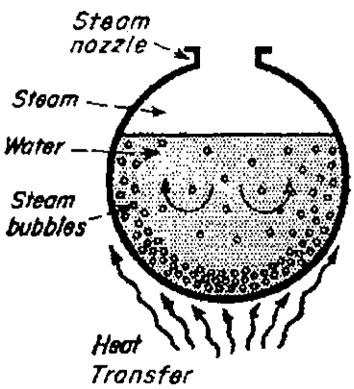
As the evaporation pressure rises, the natural circulation force of the boiler water decreases. Even when the drum is located at a high level, the boiler water cannot be made to recirculate smoothly in the line. A good solution to this problem is to install a circulation pump on the downcomer pipe for forced circulation of the water. With this configuration, it will not be necessary to install the drum at a high level. Therefore, the entire system will have a smaller dimension in height, and will require smaller floor space and smaller boiler capacity. As a result, the construction of the entire facility will be easier.

3. Once-through Boiler (traditionally 10 to 17 MPa, and more recently 24 to 25 MPa)

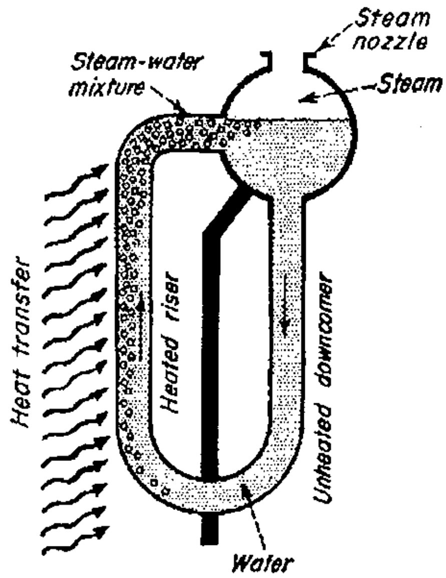
When the steam pressure exceeds the critical pressure (22.12 MPa), the mixed condition of water and steam is lost. When heated, the feed water immediately changes from saturated water into steam. The once-through boiler is a system in which feed water under pressure is forced into the boiler by a feed water pump, and flows through the economizer and the superheater, absorbing the heat. The feed water thus evaporates, and is superheated to change into a superheated steam. The resulting steam is sent to the turbine. No drums are required and small-bore water pipes can be used. This type of boiler has many advantages: lightweight pressure part, small thermal capacity, and high responsiveness for changing load. However, it requires high-performance feed water pumps, a high-purity feed water treatment system and a high-precision automatic boiler control system.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO10-3
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Type of Boilers			



(a)



(b)

Remarks	Revisions	
	2003/Nov.	Original

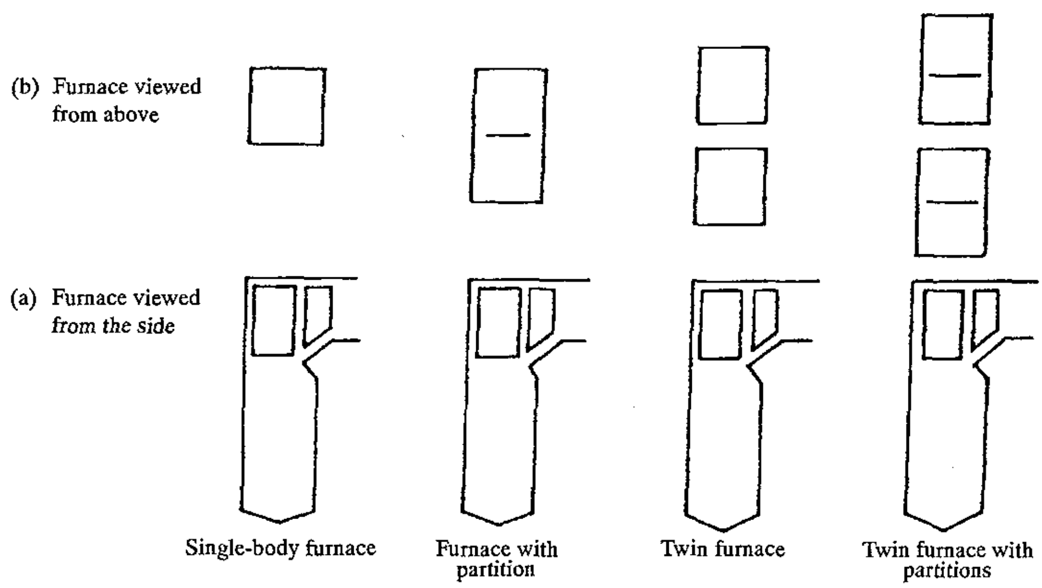
Category				Document No.BO11-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Boiler and Its Main Auxiliary Equipment (1)			

A boiler system consists of burner, evaporation tubes, rear heat transmission, reheater, gas duct, air duct and auxiliary equipment.

Boiler Main Body

(1) Furnace

A furnace consists of evaporation tubes. Various types of furnaces are available. The boiler's main body has a structure that enables the correct water flow rate in the boiler water circulation line depending on the heat absorption in the furnace.



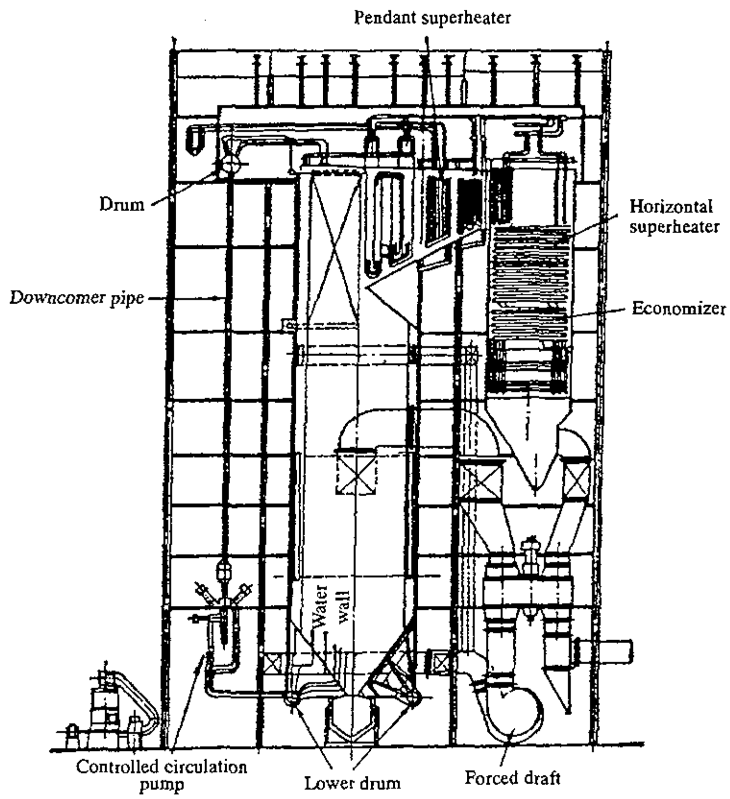
Types of furnace

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO11-2**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	**Boiler and Its Main Auxiliary Equipment (2)**			

The dimensions (depth and width) of a furnace are determined, taking into account the position of the burner. The essential point is that flames should not touch the water wall of the furnace. Water wall tubes (evaporation tubes) which comprise a furnace are made of steel and have a diameter of 60 to 75 mm in a natural circulation boiler, 40 mm in a controlled circulation boiler, and 20 to 50 mm in a once-through boiler.

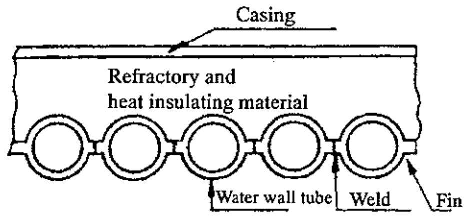
These types of boilers are radiation boilers in which the furnace has a large radiation heating surface and has a small contact heat transmission area. The water in the evaporation tubes boils under the effect of the radiation of the combustion heat on the burner provided on the furnace. The outer surfaces of the evaporation tubes are covered with a refractory and heat insulating material for preventing the internal heat from radiating to the outside. This refractory and heat insulating material is further covered with a thin steel casing. Especially with a pressurized combustion furnace whose inner pressure is higher than the atmospheric pressure, an air-tight welded casing is used to prevent the combustion gas from leaking to the outside.



Controlled circulation boiler (coal burning thermal power station)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO11-3
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Boiler and Its Main Auxiliary Equipment (3)			



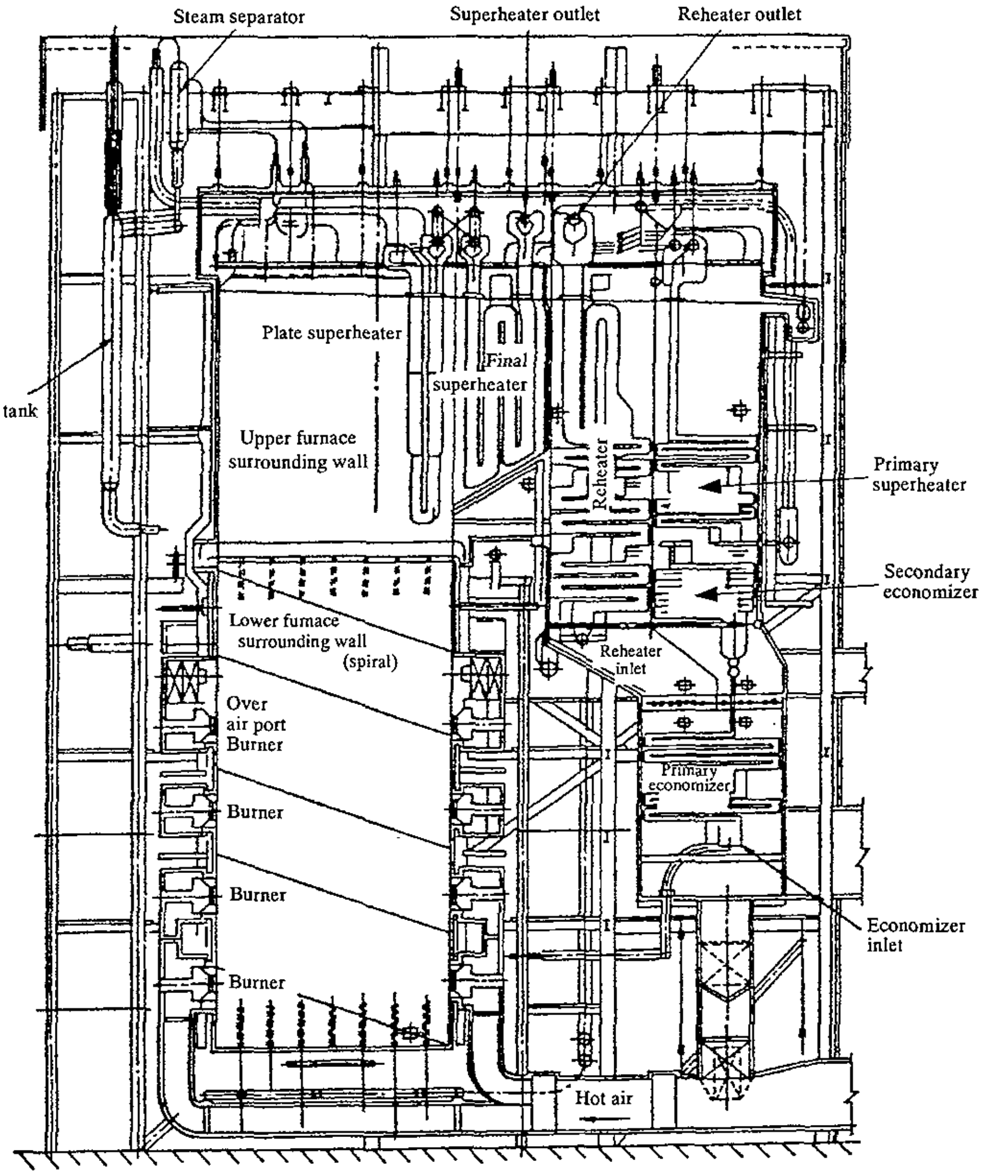
Section of water wall tubes

The evaporation tubes have fins that increase the heat transmission area.

A recent result of technical development is the spiral supercritical pressure once-through boiler that can be operated under different pressures depending on the changing load. This type of boiler is characterized by the spiral windings of evaporation tubes provided on the furnace and the steam separator at a specified angle in relation to the horizontal line to homogenize the collection of heat in the evaporation tubes. Only the upper part of the furnace has vertically installed evaporation tubes since this part only contains steam separated from water. This type of boiler has a greatly improved efficiency: it is free from the mixed condition of steam and water under supercritical pressures and can be operated with partial or full load.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO11-4
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Boiler and Its Main Auxiliary Equipment (4)			



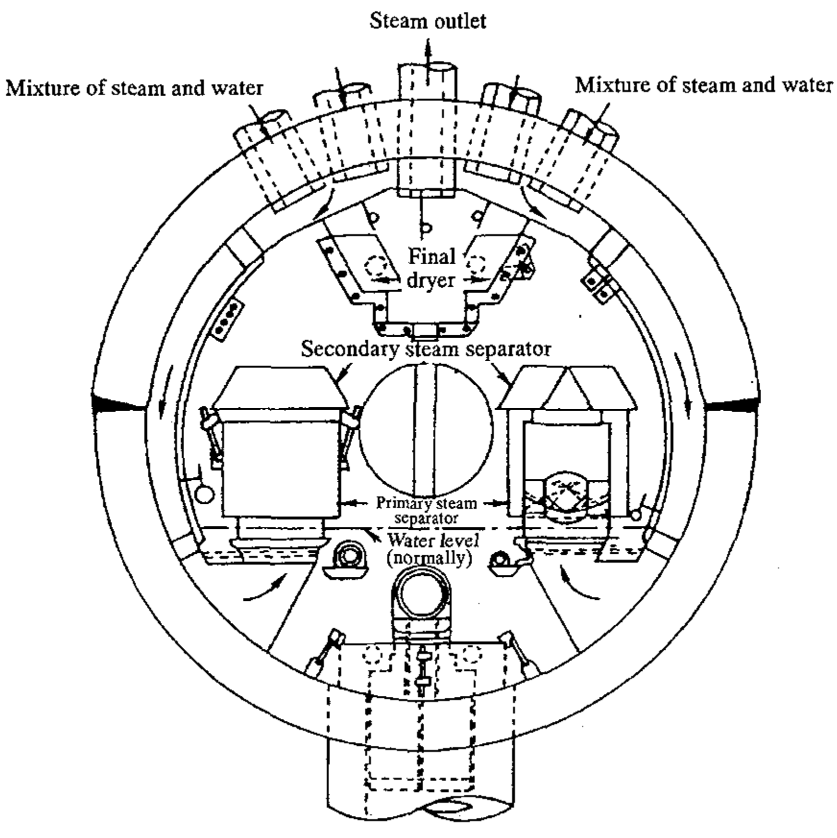
Supercritical once-through boiler for operation with variable pressure

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO11-5**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	**Boiler and Its Main Auxiliary Equipment (5)**			

(2) Drum

The drum of a natural circulation boiler or a controlled circulation boiler has a structure shown. After passing through the economizer, the feed water is sent to the main downcomer and the lower water drum and then to the evaporation tubes. Water is separated from the saturated steam generated in the evaporation tubes. This separated water is conducted to the same main downcomer and the steam is transferred to the dryer provided on the upper portion of the drum where a dry steam of liquid water content of less than 0.1% is produced and sent to the superheater.



Internal structure of the steam drum in a controlled circulation boiler

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO12-1**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	**Boiler Auxiliary Equipment (1)**			

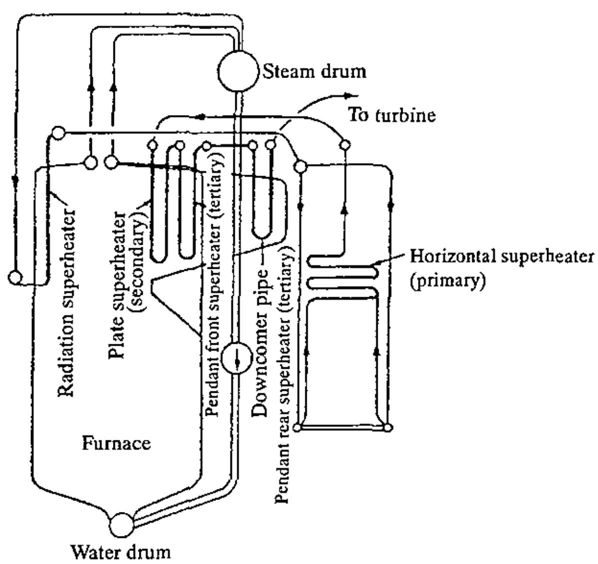
(1) Superheaters

A superheater is a device which heats a saturated steam generated in the evaporation tubes up to the temperature of the steam used in the turbine. Differentiated by the type of heat transmission, radiation superheater, contact superheater and radiation and contact superheater are installed at the positions shown in. Two installation positions are adopted for superheaters: vertical superheater and horizontal superheater. The pipes of the superheater are made of molybdenum (Mo) steel, chrome-molybdenum (Cr-Mo) steel or chrome-nickel (Cr-Ni) steel because they are exposed to high temperatures.

Generally, the ratio of the superheater's heating area to the boiler's total heating area is 10 to 30%, while the ratio is 50 to 70% in recent large boilers.

(2) Reheaters

A reheater is used to heat again the steam coming from the outlet of the turbine high-pressure part. A reheater has almost the same structure as a superheater. Reheaters are installed in the same locations as superheaters. A reheater contains an internal pressure of 3 to 5 MPa. For this reason, all pressure drops in a reheater may not exceed 10% of the internal pressure.



Installation of water drum and superheaters

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO12-2
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Boiler Auxiliary Equipment (2)			

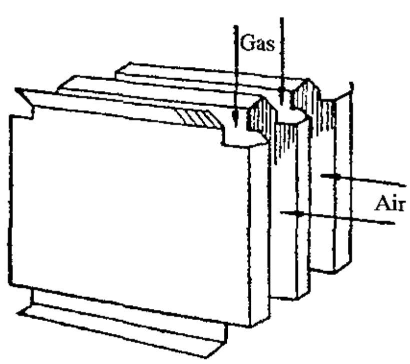
(3) Economizers

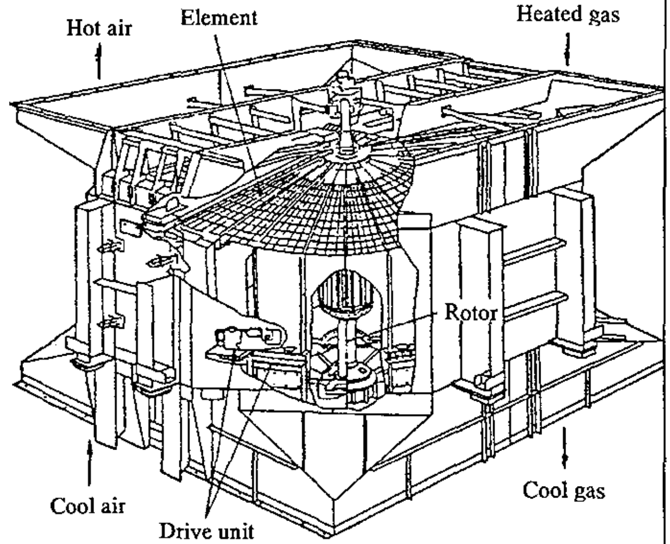
Economizers are installed in the gas duct to heat the feed water with the retained quantity of heat of the exhaust gas up to a temperature near the saturation temperature. Economizers enhance the thermal efficiency of the plant. To support directly the feed water pressure, economizers are based on steel pipes of 35 to 50 mm in diameter. Economizers play the role of hot water storage tanks, ready for responding to sudden changes of the load.

(4) Air preheater

An air preheater is installed in the gas duct near the outlet of the economizer. It recovers the remaining heat of the flue gas and heats the combustion air, enhancing the boiler's thermal efficiency. Differentiated by the type of heat transmission, two types of air preheaters are used: transmission preheater and regeneration preheater.

A transmission air preheater transmits the heat of a heated gas to the air by full-layer heat transmission. Transmission air preheaters are used for medium- or small-capacity boilers. A regeneration air preheater puts a full-layer plate in contact with a heated gas for a specified period of time to make it absorb the heat and exposes the full-layer plate to the air for another specified period of time to transfer the heat to the air. The Jungstrom air preheater is widely used for large-capacity boilers.





Structure of a steel plate air preheater

Jungstrom air preheater

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-1
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Safety Valves (1)			

1. *The boiler and its accessories must be equipped with the safety valves as* stipulated in the following items. However, for the low pressure side of the pipe stipulated in Item 9 and the boiler accessories stipulated in Item 11, relief valves having equal capacities and set pressures to those of the safety valves stipulated in the respective corresponding items can be equipped in place of the safety valves only in case the pipes and boiler accessories are not directly connected to the boiler or steam turbine.

(1) The safety valves shall be spring loaded safety valves or safety valves with a spring loaded pilot valve being in conformity with the specifications notified separately. However, the total capacity of the safety valves with a spring loaded pilot valve must not exceed half of the total necessary of the safety valves stipulated in Items 4 through 11, except in case relief valves are equipped in place of the safety valves.

(2) The stems of the safety valves and spring loaded pilot valves must vertical.

(3) The safety valves must be installed in an easily inspectable condition.

(4) For a circulation boiler with a superheater, the following provisions shall be applied.

a. Install at least one safety valves on the drum and superheater outlet respectively.

b. The total capacity of the safety valves must be not smaller than the maximum designed steam capacity of the boiler. In this case, the total capacity of the safety valves to be installed on the drum must be not smaller than 75 percent of the maximum designed steaming capacity of the boiler and he total capacity of the safety valves to be installed at the superheater outlet must be not smaller than the capacity required for keeping the temperature of the superheater not higher than its deign. (In case it exceeds 15 percent of the maximum designed steaming capacity of the boiler, 15 percent of the maximum designed capacity of the boiler.

c. In connection with (b): in the case of a boiler equipped with an automatic combustion control device and a device which cut off fuel supply quickly with a pressure not higher than 1.06 times the maximum allowable working pressure of the boiler, the capacity of a pressure relieving which is actuated automatically by a pressure not higher than the maximum allowable working pressure of the boiler can be included in the capacity of the safety valves. (In case it exceeds 30 percent of the maximum designed steaming capacity of the boiler, 30 percent of the maximum designed steaming capacity of the boiler).

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-2
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Safety Valves (2)			

d. The set pressure of the safety valve(s) installed on the drum shall be as follows:

i) In case of one safety valve: The set pressure of the safety must be not higher than the maximum allowable working pressure of the boiler. In case the boiler is equipped with a pressure relieving device which is automatically actuated by a pressure not higher than the maximum allowable working pressure of the boiler, the set pressure can be reduced to not higher than 1.03 times the maximum allowable working pressure of the boiler.

ii) In case of two or more safety valves: The set pressure of one of them shall be in accordance with the provision in (i) and the set pressure of the other safety valve(s) shall be not higher than 1.03 times the maximum allowable working pressure of the boiler.

e. The set pressure of the safety valve(s) installed on the superheater shall be lower than that of the safety valve(s) install on the drum.

f. The blow-down pressure of the safety valve(s) shall be not higher than 0.07 times its set pressure.

(5) For a circulation boiler which is not equipped with a superheater, the provisions shall also apply.

a. Two or more safety valves shall be installed on the drum. For a boiler with a heating area of not more than 50 m^2. the number of safety valves may be reduced a one or more.

b. The total capacity of the safety valves shall not be smaller than the maximum designed steaming capacity of the boiler.

(6) For a forced circulation boiler, the following provisions shall apply.

a. One or more safety valves shall be installed on the outlet of the boiler and the steam passing part (excluding reheater) respectively.

b. The total capacity of the safety valves must not be smaller than the maximum designed steaming capacity of the boiler. In this case, if the boiler is equipped with a superheater, the total capacity of the safety valves to be installed at the outlet of the boiler must be not smaller than the capacity required for keeping the temperature of the superheater not higher than its design temperature. (In case it exceeds 15 percent of the maximum designed steaming capacity of the boiler, 15 percent of the maximum designed steaming capacity of the boiler.)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-3
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Safety Valves (3)			

c. In connection with the preceding (b): In the case of a boiler equipped with an automatic combustion control device and a device which cut off fuel supply quickly with a pressure not higher than 1.06 times the maximum allowable working pressure at the outlet of the boiler, the capacity of a pressure relieving device or starting bypass device which is actuated automatically by a pressure not higher than the maximum allowable working pressure at the outlet of the boiler can be included in the capacity of the safety valves. (in case it exceeds 30 percent of the maximum designed steaming capacity of the boiler. 30 percent of the maximum designed steaming capacity of the boiler.)

d. *The set pressure of the safety valve(s) shall be as follows:*

i) In case of installing one safety valve in a part where the maximum allowable working pressure is the same, its set pressure shall be not higher than the maximum allowable working pressure in the part. However, in case of a boiler which outlet pressure is lower than the critical pressure and which is equipped with a pressure relieving device or starting bypass device which is actuated automatically with a pressure not higher than the maximum allowable working pressure at the outlet of the boiler, the set pressure of the safety valve shall not be higher than 1.03 times the maximum allowable working pressure in the part.

In case of a boiler which outlet pressure is not lower than the critical pressure and which is equipped with an automatic control device, a device which cut off fuel supply quickly with a pressure not higher than1.06 times in the maximum allowable working pressure at the boiler, and one or more pressure relieving devices or starting bypass devices which are actuated automatically by a pressure not higher than the maximum allowable working pressure at the outlet of the boiler and having a capacity not smaller than 10 percent of the maximum designed steaming capacity of the boiler (in the case an isolating stop valve is installed on the pressure relieving device or starting bypass device, two or more) (hereinafter, this boiler shall be referred to as supercritical pressure boiler), the set pressure of the safety valve can be reduced to not higher than 1.16 times the maximum allowable working pressure at the outlet of the boiler.

ii) In case of installing two or more safety valves in a part where the maximum allowable working pressure is the same, the set pressure of one of them shall be in accordance with the provision in the preceding (i) and that of the other safety valve(s) shall be not higher than 1.03 times the maximum allowable working pressure in the part. (In case of a supercritical pressure boiler, 1.16 times the maximum allowable working pressure at its outlet).

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-4
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Safety Valves (4)			

e. The blow-down pressure of the safety valve(s) shall not be higher than 0.1 times its set pressure.

f. A supercritical pressure boiler equipped with a stop valve for starting shall be equipped with a device to record the pressure on the inlet side on the stop valve.

(7) For a rehater, the provision in the preceding Item (e) shall apply correspondingly.

Besides, the following provisions shall apply.

a. At least one safety valve shall be installed at the inlet and outlet respectively.

b. The total capacity of the safety valves must be not smaller than the maximum quantity of steam passing through the reheater. In this case, the total capacity of the safety valves installed at the outlet must be not smaller than the capacity required for keeping the temperature of the rehater not higher than its design temperature. (In case it exceeds 15 percent of the maximum quantity of steam passing through the reheater).

c. In connection with the preceding (b): In case of the reheater of a boiler equipped with an automatic combustion control device and a device which cut off fuel supply quickly with a pressure not higher than 1.06 times the maximum allowable working pressure of the reheater, the capacity of a pressure relieving which is actuated automatically by a pressure not higher than the maximum working pressure of the rehater can be included in the capacity of the safety valve(s). (Incase it 30 percent of the maximum, quantity of steam passing through the reheater).

d. The set pressure of the safety valve(s) shall be as follows:

i) In case of installing one safety valve, the set pressure of the safety valve shall not be higher than the maximum allowable working pressure of the reheater. In case the reheater is equipped with a pressure relieving device which is actuated automatically by a pressure not higher than the maximum allowable working pressure of the reheater, the set pressure of the safety valve shall not be higher than 1.03 times the maximum allow working pressure of the reheater.

ii) In case of installing two or more safety valves, the set pressure of one of them shall be in accordance with the provision in the preceding (i) and that of the other safety valve(s) shall not be higher than 1.03 times the maximum allowable working pressure of the reheater.

e. The set pressure of the safety valve(s) installed at the outlet shall be lower than that of the safety valve(s) installed at the inlet.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-5
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Safety Valves (5)			

(8) *For an independent superheater, the provisions in the preceding item shall apply* correspondingly.

(9) For a pipe equipped with a pressure reducing valve and whose low pressure side equipment connected thereto are not designed at the pressure of the high pressure side, the provision in Item 4 (d) and Item 6 (e) shall apply correspondingly. Besides, the following provision shall apply.

a. Install a least one safety valve on the low pressure side of the pressure reducing valve and close to it.

b. The total capacity of the safety valves must not be smaller than the capacity required to keeping the pressures on the low-pressure side of the pipe and the equipment close to the low-pressure side not higher than 1.06 times the maximum allowable working pressure of the respective parts when the pressure reducing valve is fully open.

(10) For the part where two or more boilers are connected which have different maximum allowable working pressures and are equipped with safety valves respectively and in which the different in set pressure in set pressure between any two lowest set pressure safety valves of different boilers is not less than 0.06 times the set pressure of the lower one, the provision in Item 6(e) shall apply correspondingly. Besides, the following provisions shall apply.

a. At least one safety valve shall be installed near the part where flows of steam from the two or more boilers join.

b. The total capacity of the safety valves must not be smaller than the maximum quantity of steam which is likely to flow from the high pressure side to the low pressure side.

c. The set pressure of the safety valves shall be as follows.

i) In case of installing one safety valve, its set pressure must not be higher than the lowest among the maximum allowable working pressures the two or more boiler concerned.

ii) In case of installing two or more safety valves, the set pressure of one of them shall be in accordance with the province in the preceding (i) and the that the other safety valve(s) shall not be higher than 1.03 times the maximum allowable working pressures of the two or more boilers concerned.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO13-6
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Savety Valves (6)			

(11) For boiler accessories (excluding pipes and accessories mentioned in Item 8 and Item 10) which pressure are apt to exceed 1.06 times their respective maximum allowable working pressures, the provision in Item 6 (e) shall apply correspondingly. Besides, the following provisions shall apply.

a. At least one safety valve shall be installed at a proper place.

b. The total capacity of the safety valves shall not be smaller than the quantity of steam or gas to be accumulated in the accessories concerned.

c. The set pressure of the safety valves shall be as follows.

i) In case of installing one safety valve, its set pressure shall not be higher than the maximum allowable working pressure of the accessories concerned.

ii) In case of installing two or more safety valves, the set pressure of one of them shall be in accordance with the provision in the preceding (i) and that of the other safety valve(s) shall be not higher than 1.03 times the maximum allowable working pressure of the accessories concerned.

2. Calculation formulas for the capacities of the safety valves to be installed in accordance with the provisions of the preceding Clause, Item 4 through 11, a pressure relieving device to be installed in accordance with the provisions in the same Clause, Items 4 through 9 and a starting bypass device to be installed in accordance with the provision in the same Clause, Item 6 shall be published by Notification.

3. The constructions of the pressure relieving device to be installed in accordance with the provision(s) in Clause 1, Item 4 through 9 and the starting bypass device to be installed in accordance with the provision in the same Clause Item 6 must be conformity with the specifications notified separately.

Remarks	Revisions	
	2003/Nov.	Original

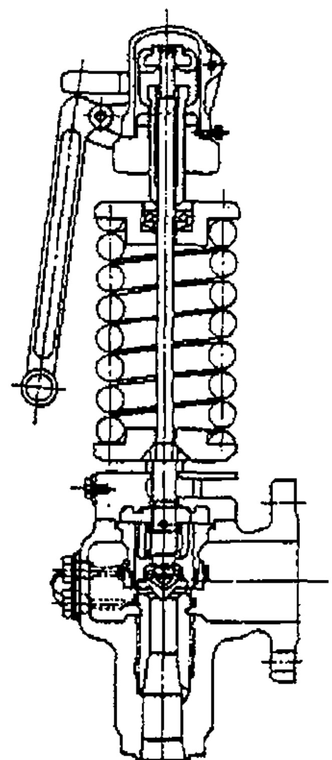
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO14-1
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	Boiler Safety Valve (1)			

Safety Valve

In case of overpressure such as the steam pressure power of a boiler goes up beyond a regulation, it is prepared in a drum, superheater and reheater. in order to protect the pressure parts.

A Safety valve test shall be examined to confirm that it is set in the regulation pressure after check repair of the Safety valve.

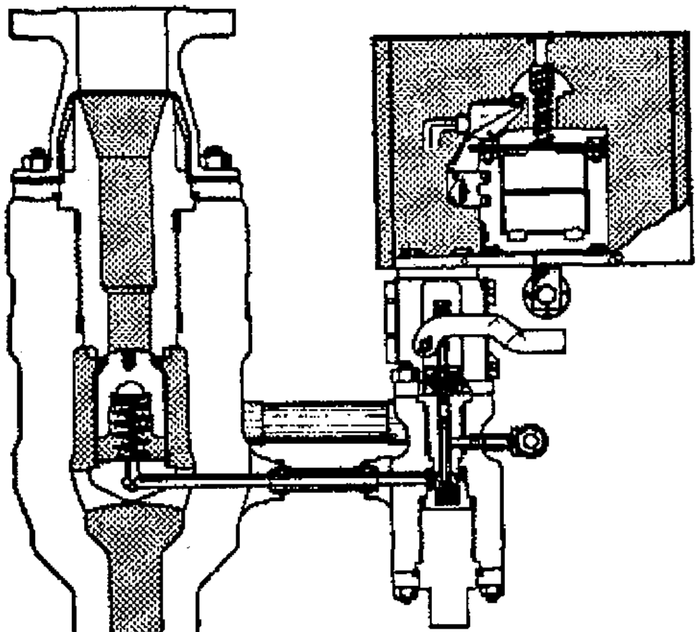
It is necessary to experienced person engage in safety valve test and it shall be make a contact with the operation person sufficiently.



Spring Type Valve

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO14-2**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-3	Safety Valves	
Title	**Boiler Safety Valve (2)**			



Power Control Type Valve(PCV)

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO15-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities(Thermal Power)	
	Clause			
Title	Fuel and Combustion (1)			

Fuel is classified into the coal slurry fuel, liquid fuel, gaseous fuel, and the solid fuel according to the using conditions.

(1) Solid fuel

Main solid fuel for thermal power generation is coal. And It is divided roughly into peat, lignite, bituminous coal, anthracite, etc. by the grade of carbonization. And main fuel is bituminous coal because of easy handing.

Character of coal is as follow.

KIND	CHARACTERISTICS	SPECIFIC GRAVITY	HEATING VALUE		Ignition°C
			HIGHER	LOWER	
Lignite	Lot of Moisture about 15 – 50 %, progress of carbonization, Low Calorific Value.	0.7～1.5	21800	20900	180～220
Bituminous coal	Low Moisture, more progress of carbonization, High Calorific Valur.	1.3～1.5	26000	24700	330～400
Anthracite	most progress of carbonization, High Carlorific Value, Low Volatilization and burning difficulty.	1.3～1.8	28900	28500	440～500

(2) Liquid fuel

There are crude oil, heavy oil, naphtha, light oil, etc for fuel of thermal power generation. Although C heavy oil was mainly used conventionally, but low sulfur heavy oil, crude oil, and naphtha have come to be used.

kind	Main ingredients[%]				Calorific Value[KJ/KG]	
	C	H2	O2	S	High	Low
Heavy Oil	86	12	–	2	44000	41400
Light Oil	85	13	0.3	0.9	45600	40600
Crude Oil	85	13	0.4	1.4	44800	41900
Naphtha	84	16	–	–	49000	45200

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO15-2
	Paragraph	2	Generating Facilities(Thermal Power)	
	Clause			
Title	Fuel and Combustion (2)			

(3) Gaseous fuel

As gaseous fuel, there are a natural gas, petroleum gas, blast furnace gas of an iron mill, coke-oven gas, etc. but LNG (liquid natural gas) is most popular for use.

LNG fuel is sophisticated fuel because of not sulfur contained and nitrogen is not included, either, there are few amounts of generating of nitrogen oxide. But LNG contents hydrogen so that moisture is generated in the furnace and boiler efficiency falls 1 to 2%.

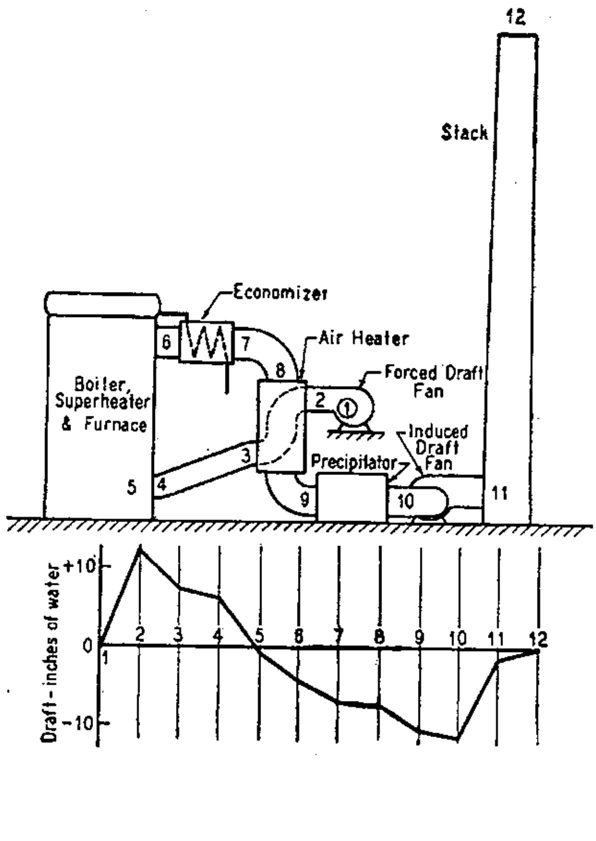
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO16
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Draft Systems			

Draft systems

The combustion process in a furnace can take place only when it receives a steady flow of air and has the combustion gases constantly removed. The steam-generator draft system induces this air and gas flow. When only a chimney is used, the system is a natural-draft system; when this is augmented with a forced-draft (FD) or induced-draft (ID) fan or both, the system is mechanical-draft system.

Small boilers use natural draft, but large units need mechanical draft to move the large volumes of air and gas against the flow resistance. Chimneys or stacks contribute only a small draft to the total needed in the large units. They help to discharge gases and fly ash high enough above ground to dilute them with air and minimize the air-pollution nuisance.



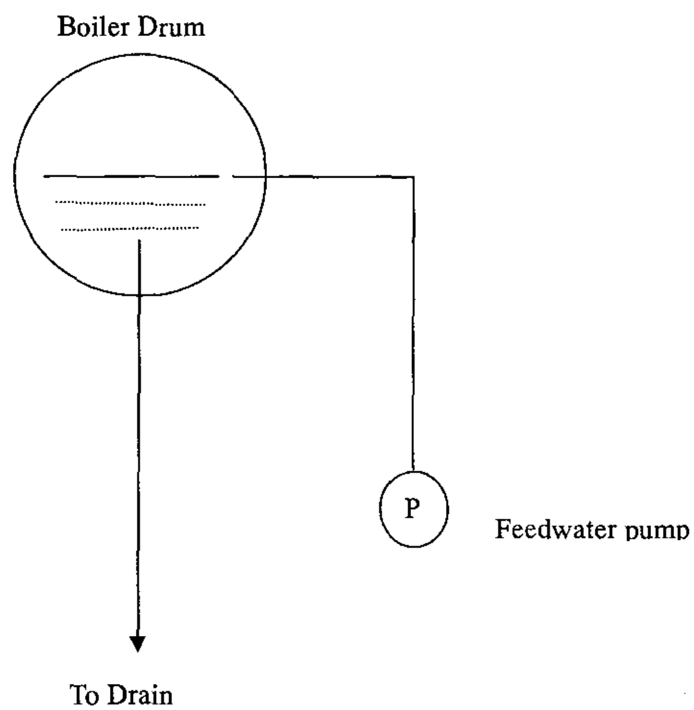
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO17**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-6	Drain off Device for Boiler	
Title	**Boiler Blowdown**			

In blowing down a boiler, part of the concentrated boiler water is drained from its water system to be replaced by feedwater. This reduces the over-all concentration in the boiler in respect to both dissolved and suspended solids.

Boiler may be blown down intermittently or continuously. Whenever the concentration builds up above the tolerance limit, the boiler is blown down manually to bring down the concentration by the fresh incoming low- concentration feedwater.

As the boiler continues steaming, the incoming feedwater leaves behind the solids to build up the concentration again slowly.



Remarks	Revisions	
	2003/Nov.	Original

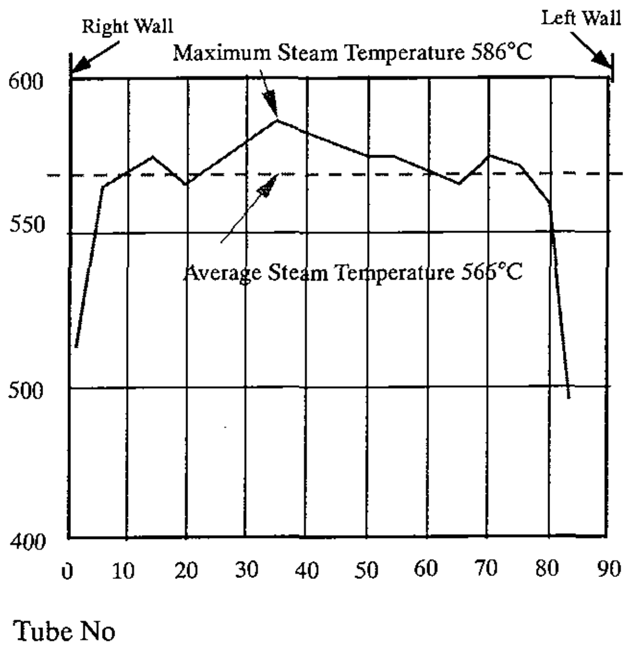
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO18**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-1	Material for Boiler and its Accessories	
Title	**Material of Boiler (Super-Heater and Re-Heater)**			

When designing Boiler, the calculation of tube-wall temperature is most important thing for choose Super-Heater and Re-Heater material.

But tube-wall temperature is not uniform so that it is considered enough condition.

The following figure reference as example.

The maximum temperature becomes higher than the average temperature.



Distribution of Steam Turbine

Remarks	Revisions	
	2003/Nov.	Original

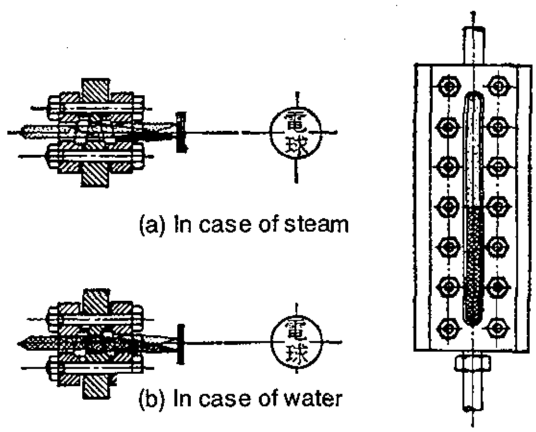
Category				Document No.BO19-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	Boiler Dram Water Level Gauge (1)			

To stable operation it is necessity to observe Boiler dram water level.

Type of Boiler dram water level Gauge

(1) Two color water level Gauge

To utilization of light beam refraction between water and steam.



(a) In case of steam

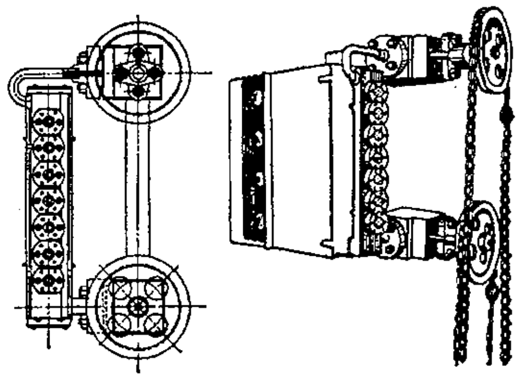
(b) In case of water

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO19-2**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-2	Structure of Boiler and its Accessories	
Title	**Boiler Dram Water level Gauge (2)**			

(2) Multi-port water level Gauge

To utilization of some Circular hard glass



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO20
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	Protective Devices			

General

Protective devices include equipment such as relays, fuses, circuit breakers, and lightning arresters. Relays are used to detect abnormal conditions and initiate action to open circuit breakers automatically. Coordination between relays, circuit breakers, and fuses is important to ensure that the circuit-opening device nearest the point of trouble opens first. Unnecessary operations and interruptions must be avoided. These devices must also have the necessary interrupting capacity or else they may blow up.

Lightning Arresters

Lightning arresters connected between the line and ground act as safety valves to protect apparatus.

When abnormal voltages appear on the circuit, they shunt the surge to ground. They provide a low- resistance path for the surge but develop a high resistance to normal power currents.

Surge voltages may result from lightning strokes or switching. Stations connected to overhead lines ordinarily need lightning arresters connected to their transformers.

Fuses

Fuses must perform two duties;

(1) carry full-load current continuously,

(2) interrupt abnormal current flows without failure.

Fuses consist of metal strips or wires within an insulated housing. Abnormal current flow melt the fuse metal strip and opens the circuit.

Protective Relays

The predominant condition for which relays are applied is a short circuit between phases or phase to ground.

The relay aims to isolate this fault from the system immediately and to keep the remainder of the equipment in operation.

Relays are also used to protect against the following conditions:

Abnormal and subnormal voltage, current, and frequency; abnormal temperature and speed; reverse power flow and polarity; reverse, open, or unbalanced phases; loss of field ; loss of synchronism.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO21**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	**Boiler Security Device**			

Generally Boiler must be equipped security devices as follows.

1. Safety Valve

   In case of overpressure such as the steam pressure power of boiler goes up beyond a regulation, it is prepared in a drum, superheater and reheater, in order to prevent danger.

   There is some kind of safety valve. Spring safety valve, power control valve (PCV).

2. Master fuel trip (MFT)

   It is the relay for intercepting combustion of a boiler at the time of an emergency.

   And it is also the relay for intercepting combustion of a boiler at the time of an emergency when the treble is outbreak boiler turbine and generator.

3. Purge interlock

   Since a boiler has fear of explosion at the time of starting or the re-ignition after MFT relay operation when non-burning gas etc. Remains in the furnace, it is emitted outside. Although this discharge is called purge, if furnace is not purged, it cannot re-ignition.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO22
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	Safety Devices for Boiler			

(1) Safety valves

Several safety valves are provided on the boiler drums and superheater headers for preventing the steam blow-off pressure from excessively rising when the steam pressure exceeds the limit value.

(2) Purge interlock

Most explosion accidents of boilers occur at the initial stage of ignition because of fuel leakage from the burner valve or insufficient purging. For this reason, the ignition process can only be performed when the air and fuel lines meet the conditions for boiler operation and the ignition initial safety conditions.

(3) Main fuel loss interlock

A thermal power station has the logic configuration in which in case of failure in the fuel, boiler water circulation and air lines or abnormal boiler furnace pressure that makes safe operation impossible, the fuel shut-off valves are closed to disable the burners.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO23
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-4	Feed Water System	

Title	Water Supply Equipment

1. A boiler (excluding spare boiler) must be equipped with two or more means of water supply equipment.
2. The water supply equipment mentioned in the preceding Clause must be able to supply a quantity of water not less than the maximum designed steaming capacity of the boiler at any time and independently. However, this provision does not apply in case the water supply equipment is feed water pumps and meets any of the following items.

(1) In case the boiler concerned is a stoker-firing boiler (excluding spreader stoker-firing boiler): In case the quantity of water to be supplied by the largest feed water pump is not smaller than 0.25 time the maximum designed capacity of the boiler and moreover, the total quantity of water to be supplied by other feed water pumps is not smaller than the maximum designed steaming capacity of the boiler.

(2) In case the boiler concerned is other than the boiler specified in the preceding Item: In case the quantity of water to be supplied by one of the water supply pumps is not smaller than 0.25 times maximum evaporation of the boiler and the total quantity of water to be supplied by other water supply pumps is not smaller than the maximum evaporation of the boiler.

3. In case the boiler concerned is the boiler specified in the preceding Clause, Item (1): In case the water supply equipment specified in Clause 1 is feed water pumps, one or more of the feed water pumps (only the one capable of supplying a quantity of water not smaller than 0.25 times maximum designed steaming capacity of the boiler) must be installed so that it must be operated on the steam from the boiler, internal combustion engine or stand-by electric power source.
4. Concerning the application of the preceding Clause (1), (2) & (3):

   In case two or more adjacent boilers are used by combining together, these boiler shall be regarded as one boiler. In this case if the boiler shall be specified in Clause 2, Item 1 is included in this group of boilers, the boiler specified in the same Item.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO24**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	**Measuring Devices**			

1. A boiler must be equipped with devices used for measuring the points specified in the following items.

(1) Circulation boiler

a. Water level in the drum

b. Pressure in the drum

c. Steam temperature at the outlet of the superheater and reheater

(2) Once through boiler

a. Steam pressure at the outlet of the superheater

b. Steam temperature at the outlets of the superheater and reheater

2. The devices to be used for measuring the points specified in the preceding Clause, Item (1)(a) shall be a glass water gauge and two or more number of this glass gauges must be installed. However, for a circulation boiler which is maximum allowable working pressure is not lower than 60 kg/cm^2, the number of glass gauge can be reduced to one or more numbers only in case two or more remote level indication gauges are installed.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.BO25
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	Hydrostatic Test			

1. *The pressure parts of the boiler and its accessories must be able to withstand* hydrostatic test with a water pressure 1.5 times as high as their respective maximum allowable working pressures without leakage.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.BO26**
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	**Example of Supercritical Boiler Control System**			

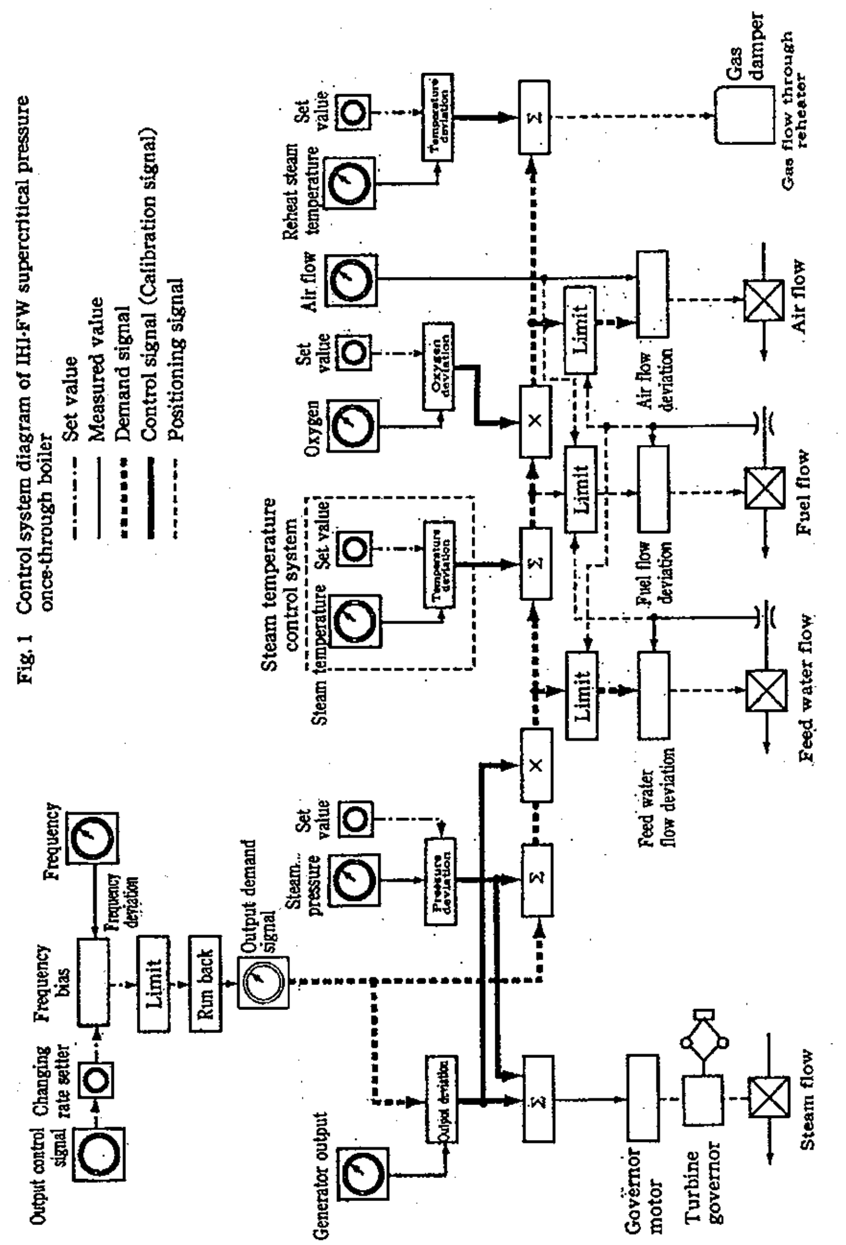
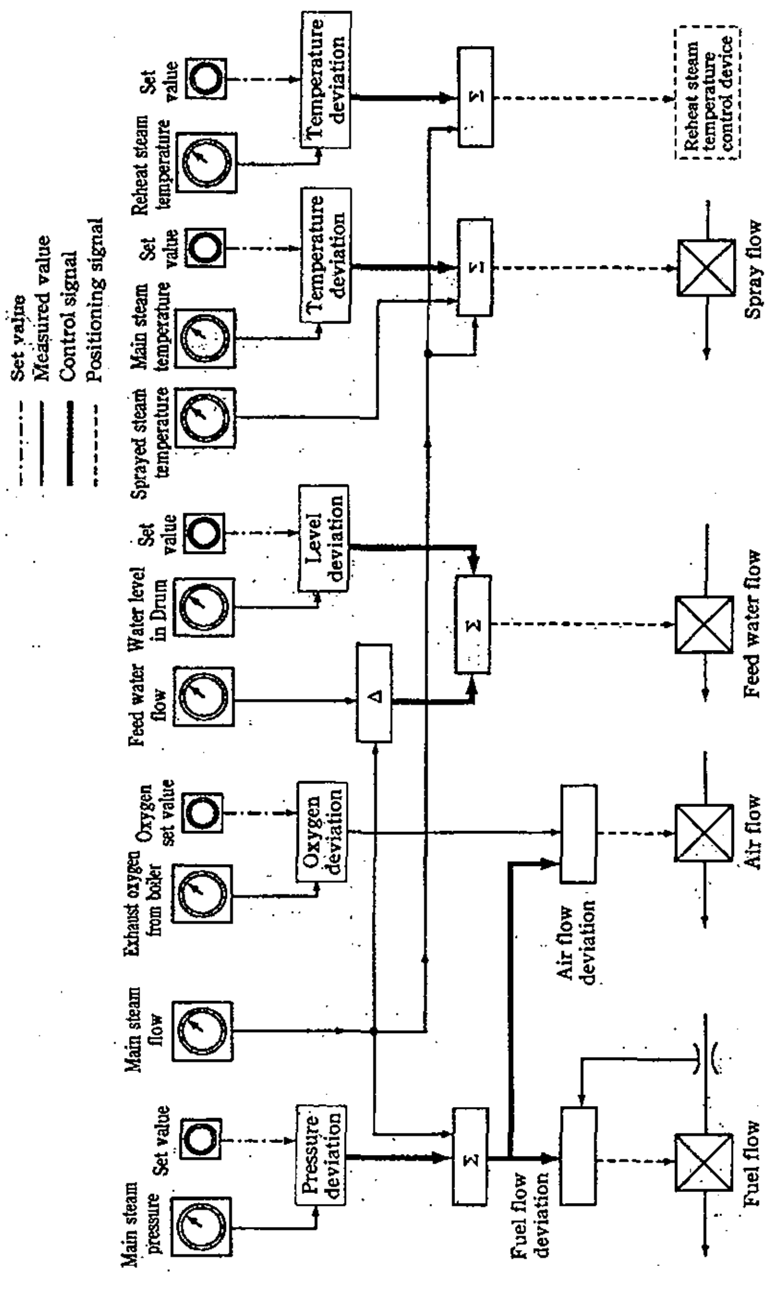


Fig. 1 Control system diagram of IHI·FW supercritical pressure once-through boiler

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO27
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	2	Generating Facilities (Thermal)	
	Clause	21-7	Monitor and Alarm System	
Title	Example of Drum Boiler Control Systems			



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.BO28-1
	Chapter	1	General Provisions	
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Environment-related Equipment (1)			

Thermal power stations use a large amount of combustion fuel. Therefore, different kinds of environmental pollution may result from exhaust gases, noise from ventilators, transformers and steam safety valves, hot waste water from condenser coolers, cleaning drainage from auxiliary equipment such as air preheaters, used lubricating oil from turbine and auxiliary equipment, metallic debris generated during equipment repair, normal waste materials such as packing and insulating materials, and accumulated discharged dead shellfishes after equipment repair.

Even in the initial stages of designing a thermal power station, these items should be considered. In fact, the selection of facility site and the designing of the equipment specifications are based on minute investigation of the topographic and meteorological conditions of the site and the results of an environmental assessment so that a thermal power station is adapted to the local conditions and needs. More specifically, the following environment-related measures are taken:

1. Air Pollution

(1) Particle collectors (dust collectors)

Particle collectors (dust collectors) are installed to remove dust of smaller than 0.02 mm and sulfates contained in the exhaust gas. Electric particle collectors which ionize dust are used. The overall collecting ratio for a thermal power station is 90 to 99%.

(2) Flue gas desulfurizer

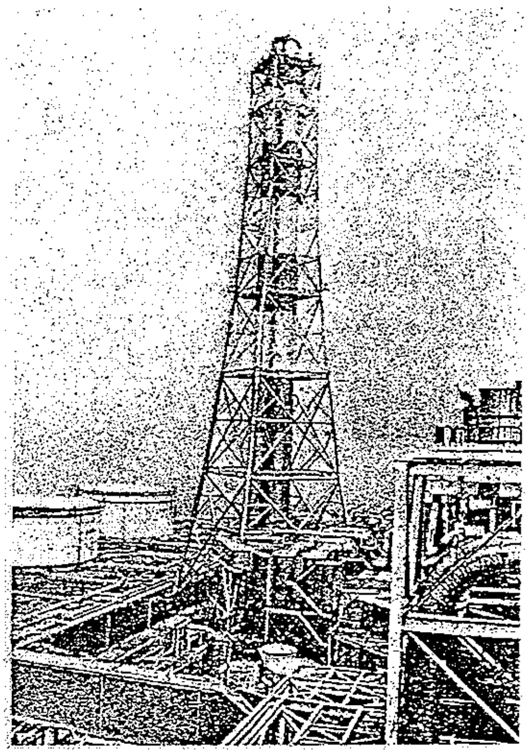
The most widely used desulfurizer is based on the wet coal plaster method.

(3) Chimney stack

Chimneys are centralized as stacks to retain the temperature of the flue gas as far as possible and accelerate the flue gas rate to rapidly diffuse it into the atmosphere and reduce the surface concentration of the flue gas.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.BO28-2
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Environment-related Equipment (2)			



Chimney stack

(4) NO_x limiter

NO_x, a factor of photochemical smog, is generated in a large amount while fuel is burning at high temperatures or with much oxygen. To limit the amount of NO_x, a low-NO_x burner for preventing high-temperature combustion, a gas-mixed ventilator for thin-oxygen combustion and a two-stage combustor are provided.

(5) Combustion control

Low-sulfur fuel is used and low-O_2 operation (with minimum surplus air) is aimed at. Different types of fuel are used for operating a power station depending on the current meteorological conditions: an ultra-low sulfur fuel is used during an air pollution alert period. In emergency cases, the station output is lowered to reduce the amount of flue gas.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	1	General Provisions	Document No.BO28-3
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Environment-related Equipment (3)			

2. Noise

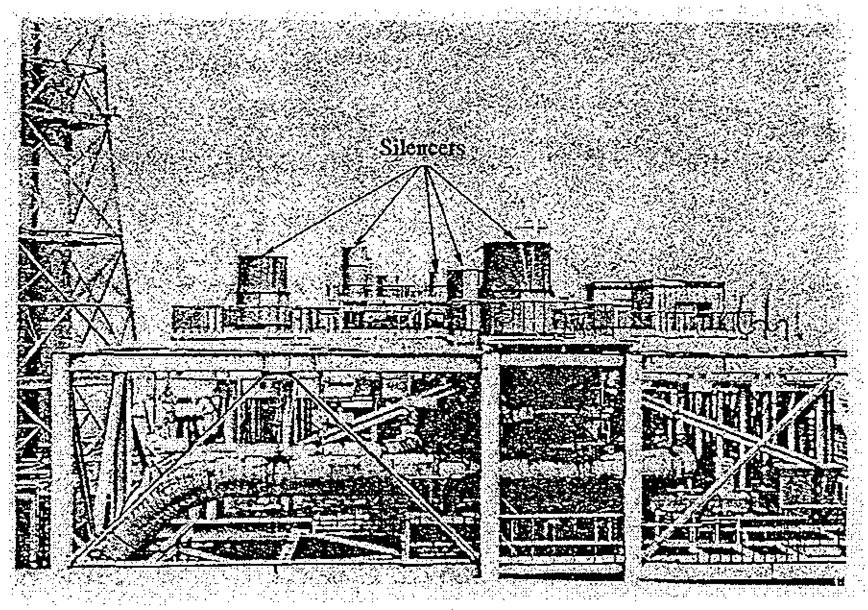
Thermal power stations are generally located at sufficient distances from residential or commercial areas. Operators of thermal power stations take various measures against noise in accordance with the local ordinances.

(1) Use of low-noise equipment

Most of the rotating devices installed in a power station have features for noise reduction. In particular, the outdoor-use equipment and devices are those specially designed for noise reduction and the stationary equipment including transformers have low magnetic flux density and are equipped with low-noise cooling fans.

(2) Sound insulating fences

If the measures concerning the equipment are not sufficient for reducing the noise to a required level, noise fences lined with a noise absorbing material are installed around the equipment. Additionally, warehouses for storing the equipment are constructed as required.



Silencers

Remarks	Revisions	
	2003/Nov.	Original

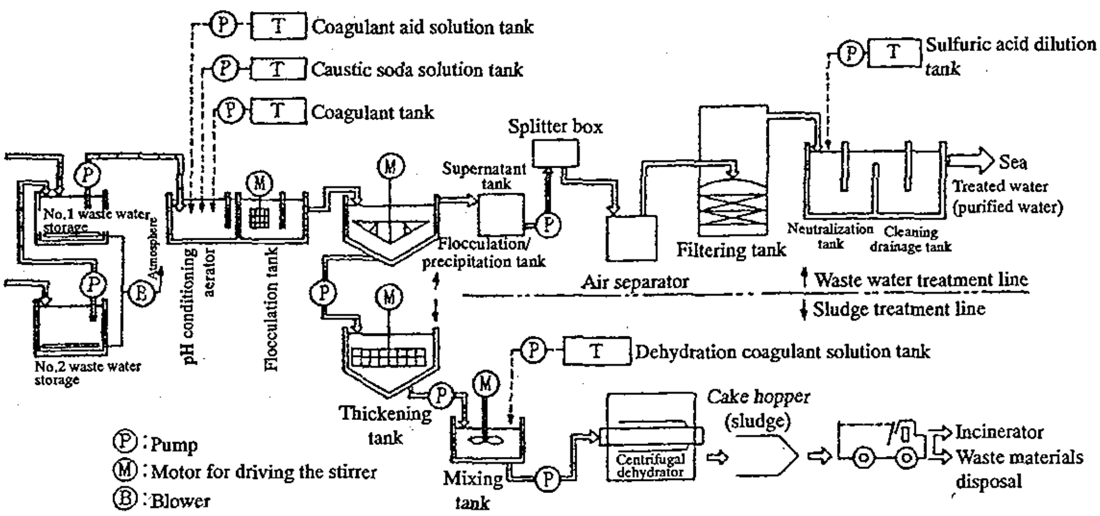
Category	Chapter	1	General Provisions	Document No.BO28-4
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Environment-related Equipment (4)			

(3) Silencers

Silencers are provided on the safety valves for boiler drums and headers to limit the noise generated during a blow-off.

3. Water Pollution

A global waste water treatment system is installed for processing the waste water from the plant to safeguard the water in the environment . The cooling water for condensers is collected at the depth of the low-temperature sea to reduce the consumption of cooling water.



Integrated waste water treatment system

4. Treatment of Waste Materials

Disposal of used oils is commissioned to the approved enterprises. Large quantities of shellfishes removed from the drainage during cleaning are disposed of at the specified external site or are burnt to ashes in the incinerator.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.BO29
	Paragraph	6	Prevention of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Environmental Consideration (Thermal Power)			

The three classes of emissions which are of major concern are nitrogen oxides, sulfur oxides, and particulate matter.

Nitrogen Oxides

With respect to firing systems, each steam generator manufacturer has developed specific design concepts for reducing nitrogen oxides. The common characteristics of all of these designs, however, included a careful regulation of the fuel/air ratio in the firing zone where the major fraction of the fuel nitrogen compounds are liberated and control of the heat liberation pattern in the furnace postcombustion reduction methods utilizing reagents with or without catalysts are somewhat similar in concept among the steam generator suppliers.

Particulate Control

The traditional particulate control device in power plant application has been the electrostatic precipitator. In recent years, fabric filters(also called baghouses) have become increasingly popular.

In electrostatic precipitation, suspended particles in the gas are electrically charged, then driven to collecting electrodes by an electrical field; the electrodes are rapped to cause the particles to drop into collecting hoppers. This process differs from mechanical or filtering processes in which forces are exerted directly on the particulates rather than the gas as a whole. Effective separation of particles can be achieved with lower power expenditure, with negligible draft loss, and with little or no effect on the composition of the gas.

Flue-Gas Desulfurization Systems

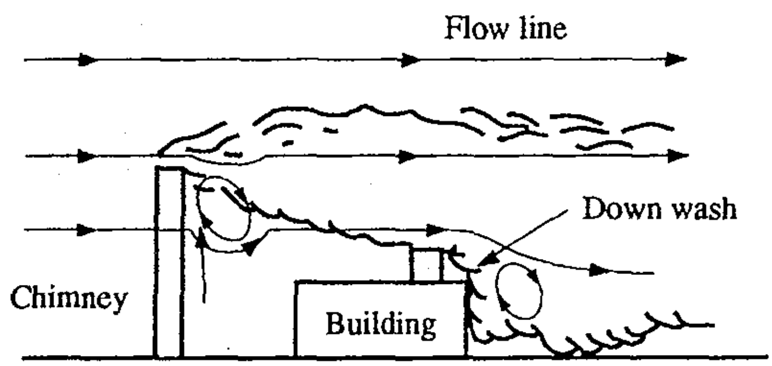
The most common FGD system is a lime/limestone wet scrubber. After the flue gas has been treated in the precipitation(or baghouse), it passes through the induced fans and enters the SO_2 scrubber. If the required SO_2 removal efficiency is less than 85%, a fraction of the flue gas can be treated while bypassing the rest to mix with and reheat the saturated flue gas leaving the scrubber.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.BO30
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Downwash of Smoke			

When the wind speed is relatively high, a vertical elongated vortex is generated behind a stack and a cavity wake is generated in the leeward region of a mountain, hill, building, or other structure, as illustrated in Figure. In such conditions, the downwash of smoke can be caused by these currents and high ground level concentrations may occur.

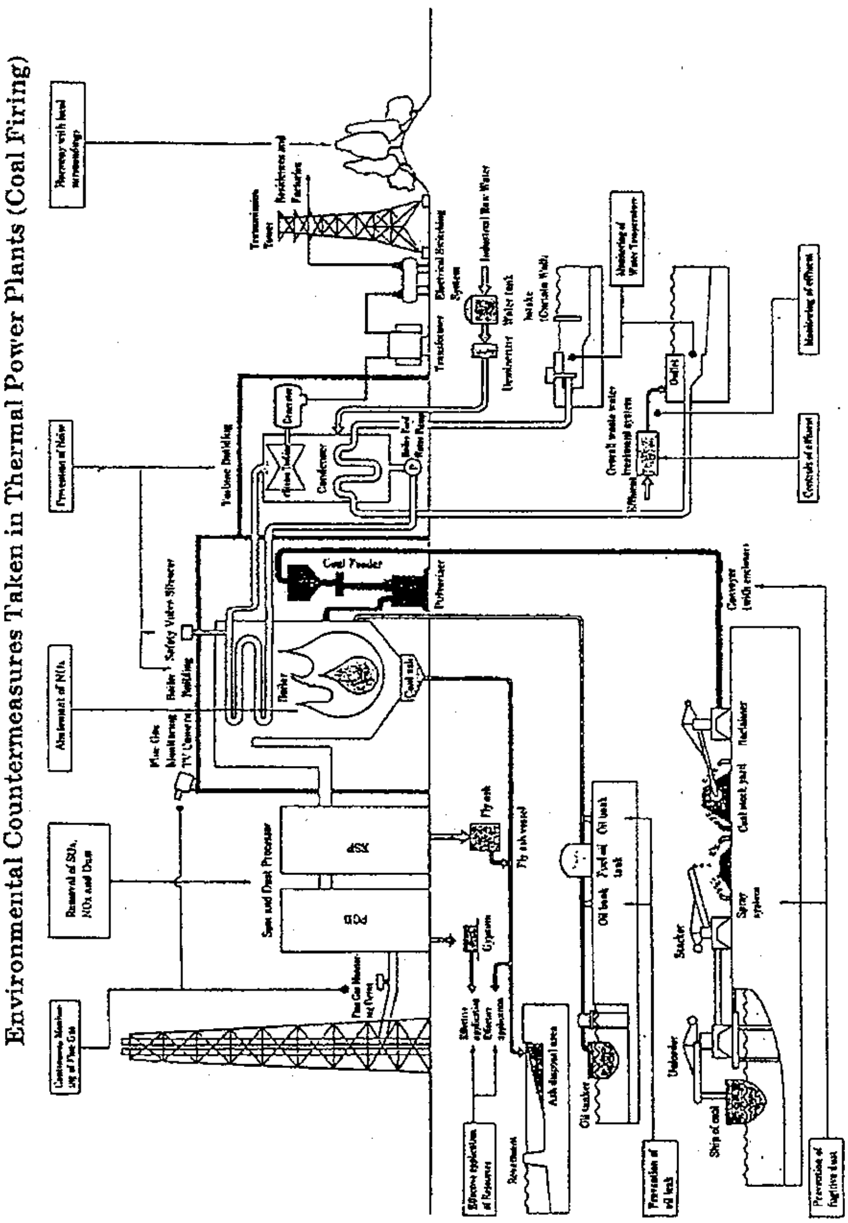
In order to reduce smoke downwash, the stack height should be at least higher than neighboring structures. Also, using high effluent velocity, or attaching a collar may be effective in abating smoke downwash behind a stack. The smoke downwash phenomenon can effectively be investigated by wind tunnel model experiments.



Downwash of smoke around stack and nearby building

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	1	General Provisions	**Document No.BO31**
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	**Environmental Countermeasures taken in Thermal Power Plants (Coal Firing)**			



Remarks	Revisions	
	2003/Nov.	Original

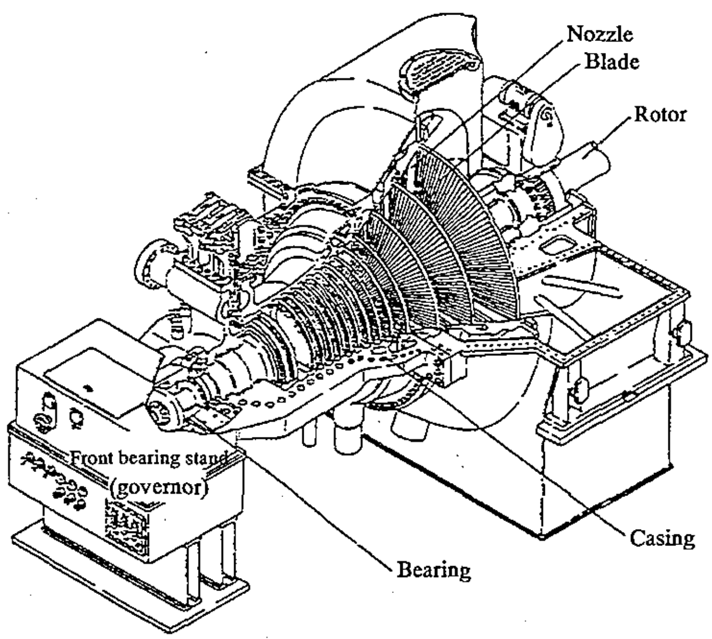
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG1-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Type of Turbines (1)			

By the action of the steam, turbines are classified into two types: impulse turbines and reaction turbines. The industrial turbine currently in operation is a combination turbine that has both impulse and reaction turbine mechanisms.

1. Impulse Turbine

Steam expands through nozzles and spouts out at a high speed against the moving blades to turn the impellers.

Many pairs of nozzles and blades are installed. These pairs successively change the steam pressure into a velocity energy that rotates the corresponding impellers. As shows a pressure compounded turbine.



Pressure compounded turbine

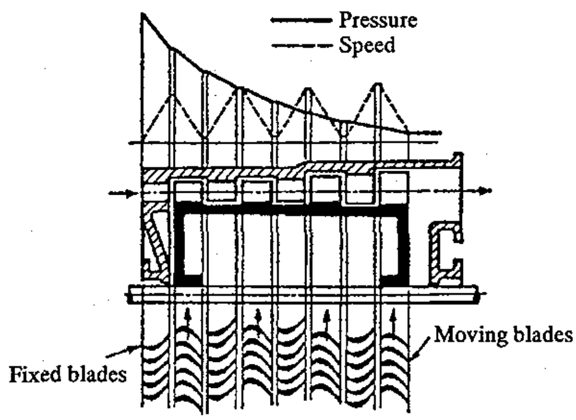
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG1-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Type of Turbines (2)			

2. Reaction Turbine

Fixed blades and moving blades are mounted alternately. Both fixed blades and moving blades ensure depression of steam pressure.

Running through the fixed blades, the steam loses a half of the specified pressure depression to accelerate its speed and gives its impulse force to the moving blades. At the moving blades, the steam loses the remaining half of the pressure depression to further accelerate its speed and spouts out of the moving blades. The reaction to the steam's spouting allows the moving blades to turn.



Reaction turbine

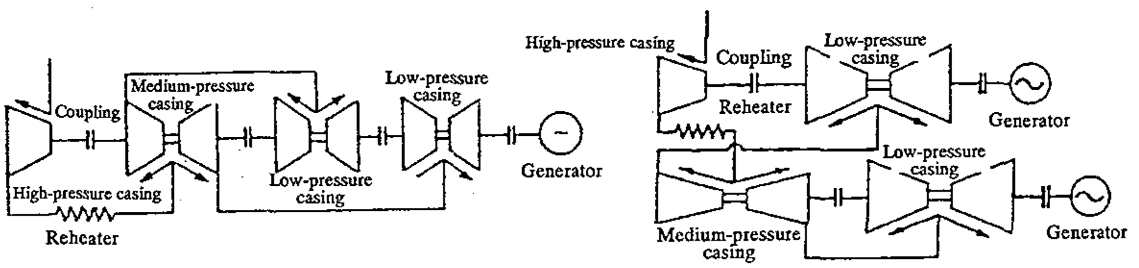
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.TG1-3**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	**Type of Turbines (3)**			

3. Combination Turbine

A combination turbine is a turbine in which the first stage consists of a impulse turbine mechanism and the remaining parts consist of reaction turbine mechanisms. An impulse impeller is used at the first stage. Large depression of steam pressure occurs at the first stage, giving high-velocity energy to the moving blades to produce a large turning force. Therefore, this combination system requires a smaller number of reaction stages and the overall length of the turbine can be reduced considerably.

By the number of axles, combination turbines are classified into two types: tandem compound turbines and cross compound turbines. By the direction of steam flow, combination turbines are classified into three types: axial flow turbines in which steam flows in parallel with the turbine shaft, double flow turbines in which steam symmetrically flows at both sides of the casing, and single flow turbines in which steam flows in one single direction in the casing. Furthermore, by the function or application, combination turbines can be classified differently: reheat regenerative turbines, condensing turbines which change turbine exhaust gas into condensate, back pressure turbines which use exhaust gas for industrial service stream, etc.



(a) Tandem compound 4-casing, 4-flow turbine (250-700 MW) (b) Cross compound 4-casing, 4-flow turbine (265-1000 MW

Types of combination turbines

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.TG2-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Turbine Main Body (1)			

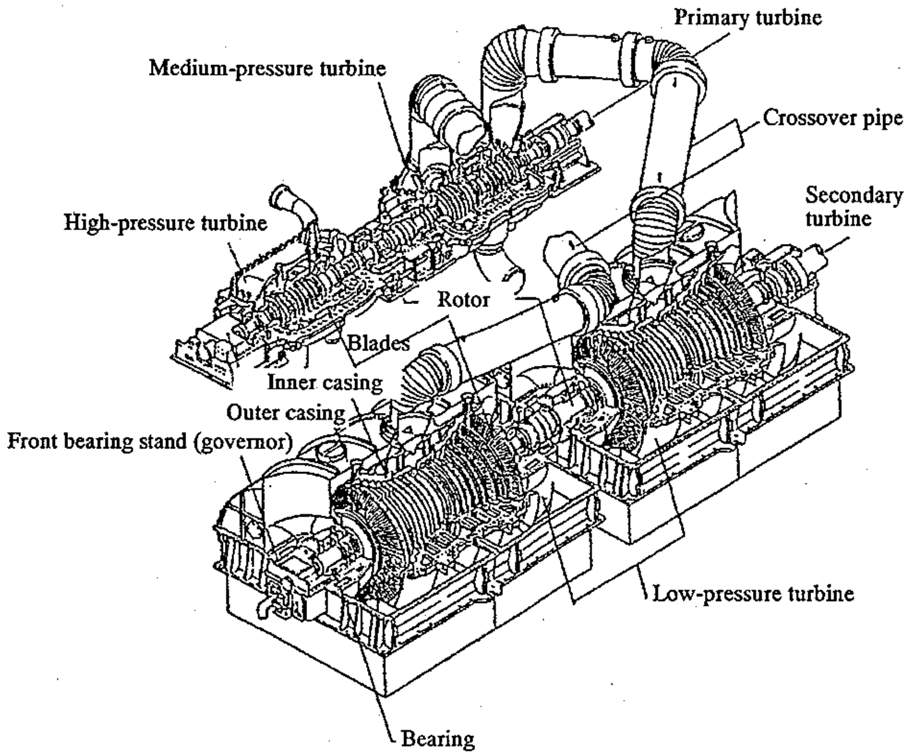
A turbine main body consists of a casing, rotors, packing, bearings and other parts.

(1) Casing

The casing is the part which covers the rotor and forms the external face of a turbine. A high-pressure or a medium-pressure casing has a double structure composed of an inner casing and an outer casing, in consideration of thermal stress, thermal strain, and thermal expansion.

Each casing consists of an upper part and a lower part which are separated from each other by the horizontal plane that includes the turbine shaft line. The upper part is jointed with the lower part by screws.

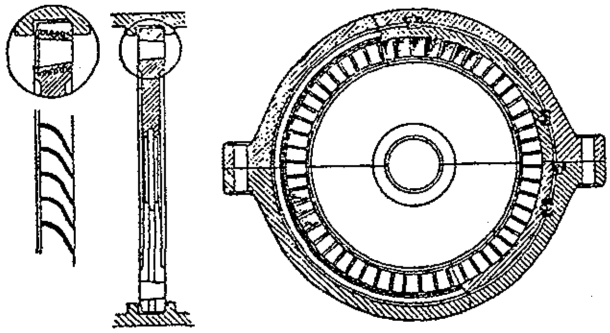
These casings are supported by the horizontal coupling plane and can be extended in the right and left and upward and downward directions. Nozzles are mounted on the partition plate in the casing. A reaction turbine incorporates fixed blades adapted to the nozzles.



Turbine main body

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG2-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Turbine Main Body (2)			

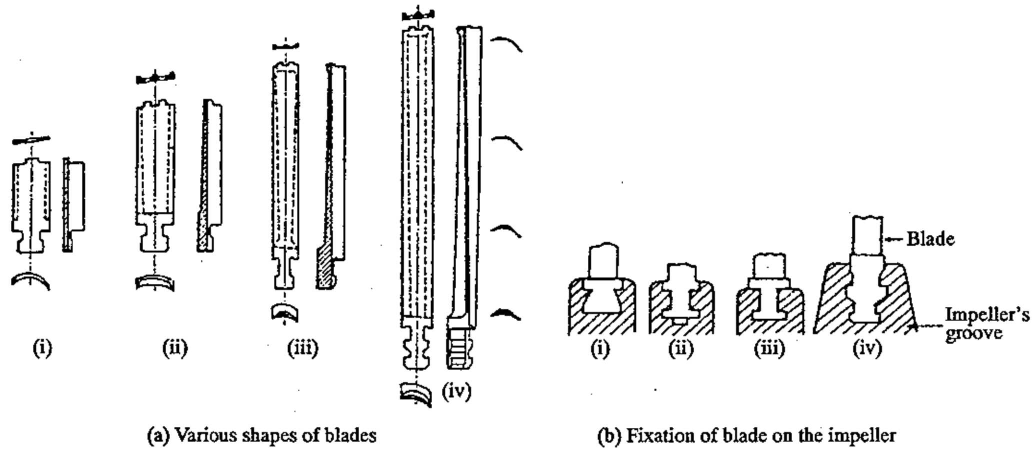


Partition plate

(2) Impeller

An impeller is a device which rotates with the steam's velocity energy and transmits torque to the generator. An impeller consists of a shaft, blades and shaft couplings. Impellers are generally constructed by forging. Several rotors are jointed with each other for an impeller because of limitations on the material. The blades rotate together with the shaft under the impact of the incoming steam. These blades are exposed to centrifugal force. The blades have the shapes as shown. The blades are firmly fixed in the grooves of the impeller. The shape of a blade depends on the impulse and reaction of the steam. In particular, the long blade for the final stage of the low-pressure unit has a strong hydrodynamic shape, on account of the vibration. The casing and impeller are exposed to high temperatures and high pressures. The impeller, which is additionally exposed to great centrifugal force, must be made of a material that has great strength at high temperatures.

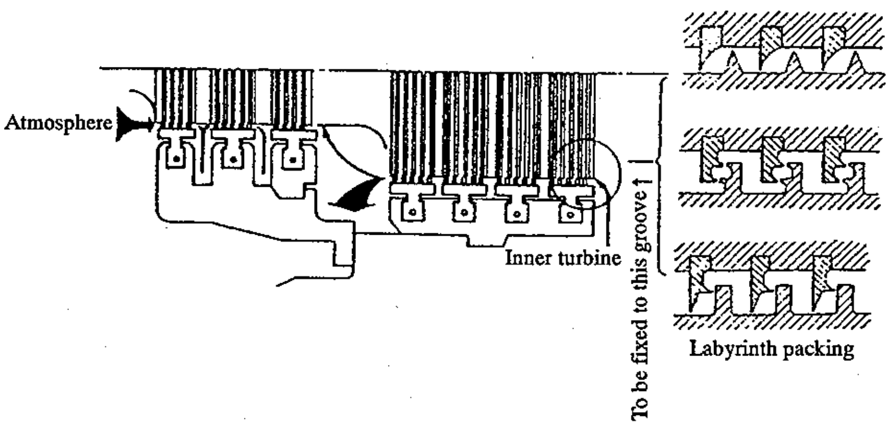
Remarks	Revisions	
	2003/Nov.	Original



Impeller

(3) Packing

The labyrinth packing that has the structure shown is used to prevent steam from flowing out of the casing. Steam flows out through the gaps between the shaft and the combs to lower the steam pressure. The steam leaking from the casing is extracted from near the outside of the packing into the gland steam condenser and is used for heating the feed water.



Fixing the packing

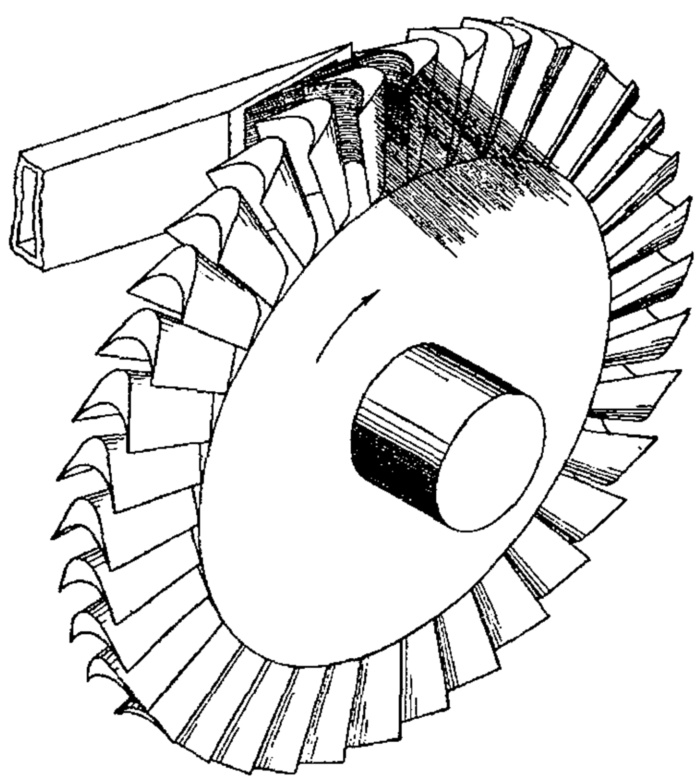
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG2-4
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Main Body (4)			

Steam turbines convert some of the energy in steam flowing through them into rotating – shaft energy. While we know that steam contains large amounts of energy, it's an unfortunate tact that not all of it can changed to mechanical shaft energy.

Turbine Elements

Steam turbines have two main working elements: (1) nozzles and (2) blades or buckets.

Everything else, such as wheels, casing, shaft, bearings, and governors, is auxiliary to the two main elements.



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG2-5
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Turbine Main Body (5)			

(4) Bearings

Bearings are important parts for supporting the turbine shaft. Two types of bearings are used: journal bearings, which support the weight of the shaft, and thrust bearings, which support the axial force. Thrust bearings support the thrust generated in the axial direction of the impeller to maintain its axial position.

(5) Lubricating oil/control oil equipment

While the turbine is operating, the main oil pump provided on the casing feeds the bearing oil and the control oil. The return oil of the bearing oil recirculates. This equipment includes a main oil pump, auxiliary oil pump, a turning gear oil pump, an oil cooler, an oil cleaner, etc.

The auxiliary oil pump feeds the turbine-related oil until the normal number of revolutions is attained.

(6) Turning gear equipment

Before a turbine is started, or after it is stopped, this equipment is operated to rotate the turbine shaft at 2 to 3 rpm so that the temperature distribution may be maintained homogeneous in the casing to prevent the shaft from bending.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG3
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	21	Steam Turbine and its Accessories	
Title	Hydrostatic Test			

1. The pressure parts of the steam turbine and its accessories must be able to withstand hydrostatic test with a water pressure 1.5 times as high as their respective allowable working pressures without leakage.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.TG4**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	21	Steam Turbine and its Accessories	
Title	**Emergency stop devices**			

1. A steam turbine must be equipped with an emergency stop device which is actuated at a speed not higher than 1.11 times its rated speed.
2. A steam turbine must be equipped with a device which interrupts the inflow of steam automatically in the cases stipulated in the following Items.

(1) In case a trouble occurred in a generator with a capacity exceeding 10,000kVA.

(2) In case vacuum of the condenser of the steam turbine having a rated output exceeding 10,000 kW made a remarkable drop.

(3) In case the thrust bearing of a steam turbine having a rated output exceeding 10,000kW was worn out or its temperature.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.TG5
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Safety Devices for Turbine			

1.11.2 Safety Devices for Turbine

In case of failure in the turbine that makes safe operation impossible, the appropriate safety devices are immediately activated to stop the turbine. These include:

(1) Emergency governor system

This system is activated when the turbine speed exceeds 110 ± 1% of the rated speed.

(2) Bearing oil pressure drop trip mechanism

This mechanism starts to work when the bearing oil pressure excessively drops.

(3) Shaft position failure trip mechanism

This mechanism starts to work when the rotor has deviated from the normal position because of wear of the thrust.

(4) Exhaust chamber temperature rise trip mechanism

In case of excessive rise of the temperature, this mechanism is immediately activated to prevent the casing from being deformed and/or vibrating excessively.

(5) Vacuum drop trip mechanism

In case of excessive drop of the vacuum in the condenser, this mechanism is immediately activated to prevent the temperature in the exhaust chamber from rising.

(6) Abnormal vibration trip mechanism

Whenever the value obtained by comparing the vibration change rate to the amount of change exceeds the specified level during start-up operation of the turbine, this mechanism is activated.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG6
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	21	Steam Turbine and its Accessories	

Title	Safety Valves

1. The steam turbine and its accessories must be equipped with the safety valve as stipulated in the following items.

(1) The safety valves shall be spring loaded safety valves or safety valves with a spring loaded pilot valve in conformity with the specification notified separately. However, the total capacity of the safety valves with a spring loaded pilot valve must not exceed half of the total necessary capacity of the safety valves except in case relief valves are equipped in place of the safety valves.

(2) The stems of the safety valves and spring loaded pilot valves must be vertical.

(3) The safety valves must be installed in an easily inspectable condition.

(4) For steam turbine accessories which pressures are apt to exceed 1.06 times their respective maximum allowable working pressures, the following provisions shall apply.

a. At least one safety valve shall be installed at a proper place.

b. The total capacity of the safety valves shall not be smaller than the quantity of steam or gas to be accumulated in the accessories concerned.

c. The set pressure of the safety valves shall be as follows.

i) In case installing one safety valve, its set pressure shall be not higher than the maximum allowable working pressure of the accessories concerned.

ii) In case of installing two or more safely valves, the set pressure of one of the them shall be in accordance with the provision in the proceeding (i) and that of the other safety valve(s) shall not be higher than 1.03 times the maximum allowable working pressure of the accessories concern.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG7
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	21	Steam Turbine and its Accessories	
Title	Alerming devices			

1. A steam turbine having a rated output not less than 400,000kW and an electric generator or other rotating bodies connected together in the same shafting must be equipped with an alarming device that functions to alarm when the maximum full amplitude value of vibration produced during turbine rotation (excluding the period of lowing turbine speed) at the principal bearings of the turbine or the portions of the shaft near these bearings exceeds the alarm value shown below.

Position of Measurement	Rated turbine speed (r.p.m.)	Alarm value (mm) For speed below Rated speed	Alarm value (mm) For speed not lower than rated speed
Bearing	3,000	0.075	0.062
	1,500	0.105	0.087
Shaft	3,000	0.15	0.125
	1,500	0.21	0.175

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.TG8**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	21	Steam Turbine and its Accessories	
Title	**Measuring devices**			

1. A steam turbine must be equipped with devices for measuring the points specified in the following Items.

   However, a steam turbine having rated output not larger than 10,000kW need not be equipped with a device for measuring the point specified in Item (7).

   a. Speed the steam turbine

   b. Steam pressures and temperatures before the main steam stop valve and the reheat stop valve

   c. Exhaust pressure of the steam turbine

   d. Oil pressure at the bearing inlet of the steam turbine

   e. Oil temperature at the bearing outlet of the steam turbine

   f. Opening of the steam governing valve

   g. Amplitude of vibration of the steam turbine

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.TG9-1**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	Governor	
Title	**Governor (1)**			

Governor

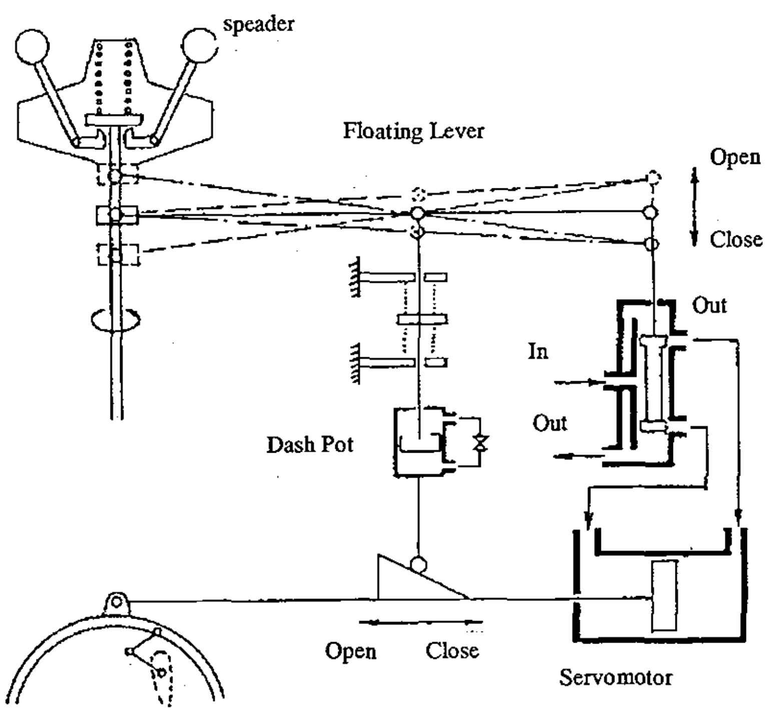
Steam turbine for the power generation needs governor that controls the turbine inlet steam flow.

This control works for the change of the load and the rotation speed.

Main governor is the equipment that amplifies the difference, detecting the rotation speed of turbine.

There are a mechanical type, an oil pressure type, and an electric type in this.

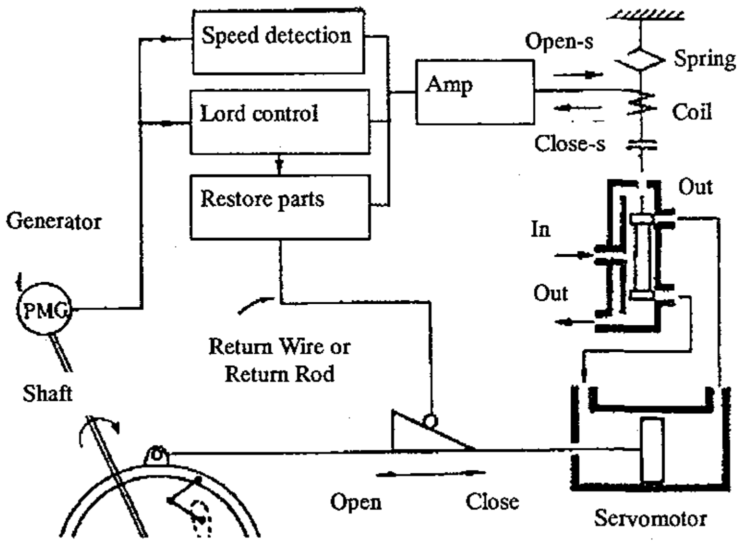
It controls turbine speed using the difference of the centrifugal force.



Mechanical type

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG9-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Governor (2)			



Electrical type

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.TG10
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			

Title	Turbine Vibration and Overspeeding

Vibration

If a rotor is perfectly uniform in its weight distribution about the center of the shaft, it can rotate at any speed up to its strength limit without vibrating, provided it remains perfectly stiff. But all turbine rotors have a certain degree of flexibility and, when supported between the bearings, they will bend under their own weight.

It is difficult to achieve perfect balance, with the result that a small unbalanced weight may be left in a rotor, even after adjustment with balancing weights.

Overspeeding

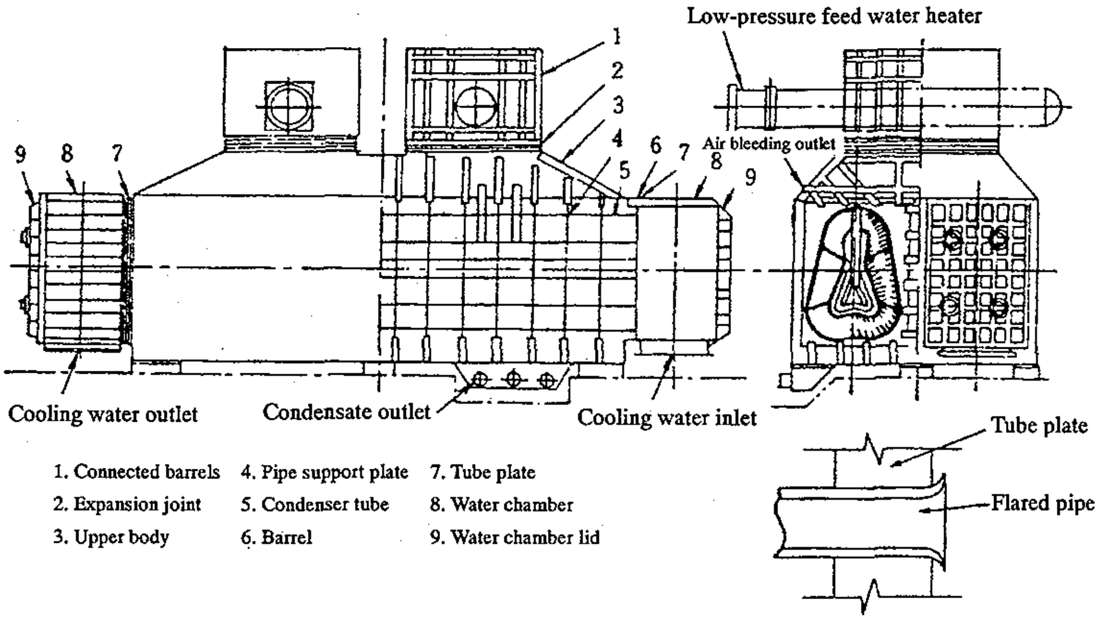
Sudden and complete loss of load will tend to overspeed a turbine. Usually the speed governor will instantly respond by closing down the control valves, reducing steam flow to the ero-load condition.

If the speed governor should fail, the rotor would quickly speed up because it would be attempting to absorb all the energy of the steam jets.

Overspeed trips or emergency governors should be tested regularly and at every opportunity to ensure their being in proper operating condition.

Remarks	Revisions	
	2003/Nov.	Original

A condenser is used to cool the steam discharged from the turbine to change it into condensate. Moreover, a condenser has the role of lowering the discharge pressure of the turbine. The resulting condensate is used as feed water to the boiler. The type of surface condenser widely used in the industry has the structure. It is a closed device equipped with many condenser tubes to which the exhaust is conducted. The exhaust condenses with the cooling water which circulates through the condenser tubes to produce a vacuum in the turbine exhaust zone.



Structure of a condenser

The barrel is composed of welded steel plates. The tube plate is made of naval brass plate. Ten thousand to thirty thousand cooling water pipes are mounted on the tube plate. These cooling water pipes have a diameter of 25 to 30 mm and have a flared end. They are made of brass or titanium. To cope with the difference of thermal expansion between barrel and pipe, a tube plate is fixed to the barrel via an expansion joint. A circulating pump feeds cooling water to the water chamber. Because of thermal expansion, an expansion joint is used to connect the condenser with the turbine exhaust chamber.

Category				Document No.TG11-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Condensers (2)			

Gases including air flowing together with the exhaust into the condenser are discharged by a bleed pump (vacuum pump). **The vacuum in the condenser** depends on the temperature of the cooling water. In normal conditions, the vacuum is controlled at **5.066 kPa** when the cooling water is at 21°C.

Circulating water pump

This pump feeds cooling water to the condensers. It has a great discharge and a small head. As a circulating water pump, a centrifugal pump or a mixed flow pump is used.

Condensate pump

A condensate pump extracts condensate accumulated in the condensate tank and sends it via low-pressure feed water heaters to the deaerator. It has a small pump discharge and a great pump head. Multi-stage turbine-type pumps are used as condensate pumps.

Bleed pump (vacuum pump)

A bleed pump discharges the air and gas entrained in the exhaust and air coming from the couplings of the turbine and accumulated in the condenser to the outside. The bleed pump maintains the vacuum and enhances the turbine efficiency. Rotary vacuum pumps and vapor pumps can be used. Currently, rotary vacuum pumps are widely used in the industry.

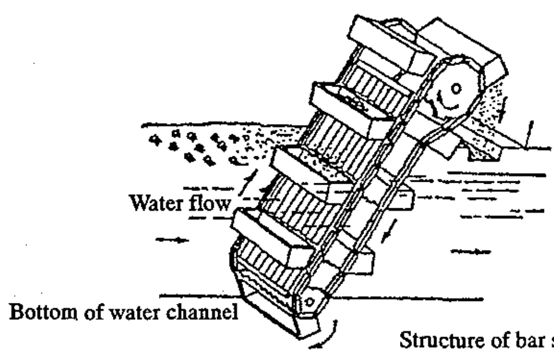
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG12-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Cooling Seawater Collecting/Discharging Equipment (1)			

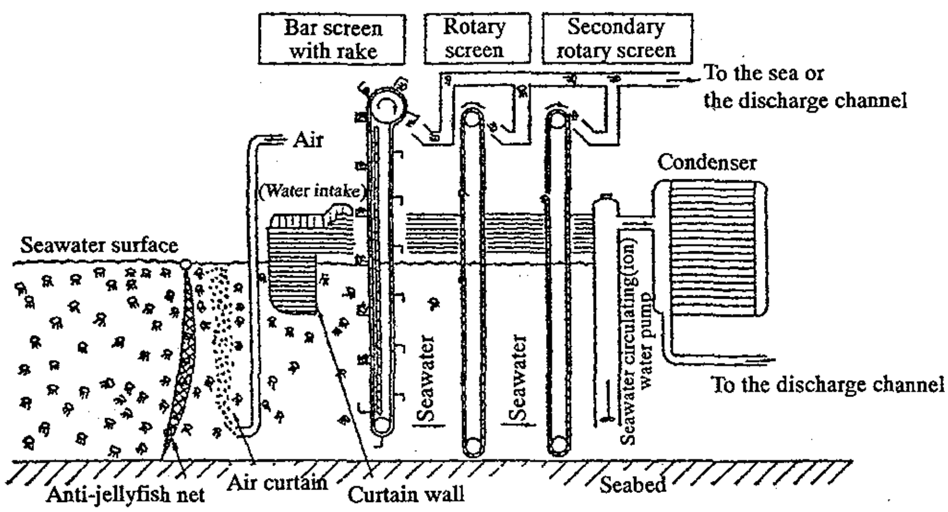
Thermal power stations are often constructed on the coastline. A large amount of seawater is used to cool and condense in the condenser the steam having completed the work in the turbine. Seawater is also used in the cooler for the cooling water for the bearings of the pumps installed at many locations in a thermal power station. Seawater flows into the water intake under the suction force of the circulating water pump and passes through the water channel and reaches the circulating water pump. The seawater is then transferred to the condenser where it is cooled. The resulting seawater passes through the drainage and is discharged through the discharge port at the opposite side of the water intake into the environment (sea).

(1) Water intake

The water intake is equipped with various devices for smooth collection of cooling water: anti-jellyfish net, curtain wall, bar screen with rake, travel screen, and stop-log.



Structure of bar screen with rake



Cooling seawater collecting/discharging equipment

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG12-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause		Thermal Power	
Title	Cooling Seawater Collecting/Discharging Equipment (2)			

1) Curtain wall: Water jet sprinkling to prevent garbage and jellyfish from entering the water intake.

2) Bar screen with rake: Collects garbage and jellyfish that have entered the water collecting line and assembles them in the dust catching pit.

3) Rotary screen: Collects on the rack fine garbage and jellyfish from the seawater and gathers them in the dust catching pit.

4) Stop-log: *Device which is installed for temporary inspection of the water collecting line at* the water intake and which prevents seawater from entering the site.

(2) Water channel

The flow rate of the seawater in the water channel should be regulated at 1 to 2 m/s in the water collecting line and 2.5 m/s in the drainage line. Water channels as open conduits or closed conduits are often used. Generally, a water channel is constructed with concrete and has a rectangular or circular section. Cleaning manholes and pumping pits are provided at appropriate locations.

(3) Water discharge port

The water discharge port is equipped with an apron that prevents it from being damaged during water discharge. The water discharge port is often provided at the opposite side of the water intake on the canal entrance.

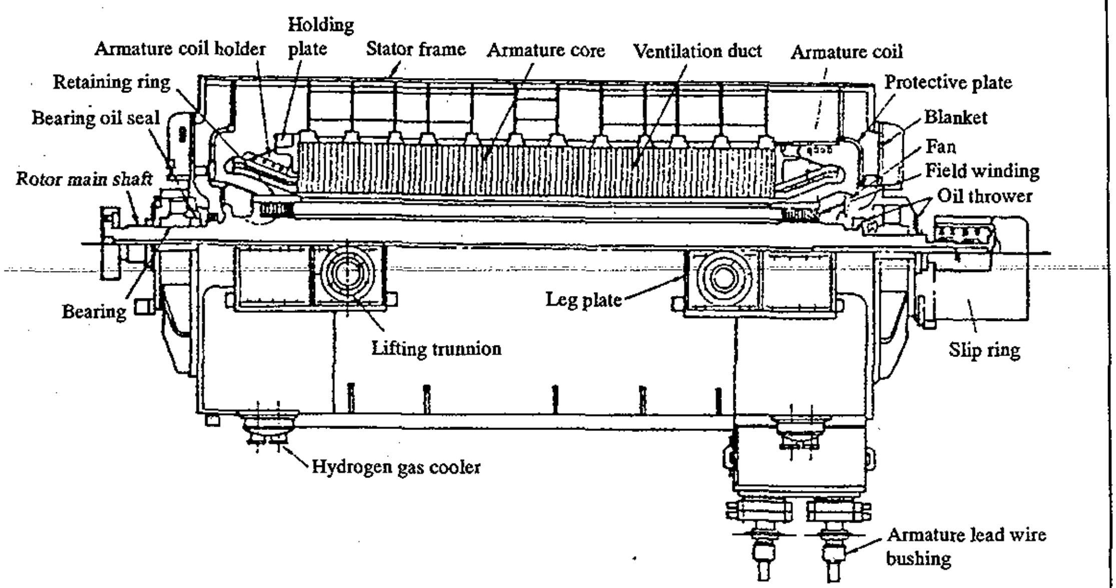
The screens detect any change of the water level at the upstream and downstream side and are automatically activated for dust removal.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG13-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Generator and Station Electric Equipment (1)			

1. Generator

This is a two-pole cylindrical revolving field generator with horizontal shaft which is usually driven by a directly-connected steam turbine. It rotates at 3,000 or 3,600 rpm. A generator consists of a stator, a rotor, bearings and a cooling system. The stator iron core is made of grain oriented silicon steel plates. With the armature coils composed of split coils, installed in the stator groove, the generator produces a large alternate current.



Structure of hydrogen-cooled turbine generator

The rotor is forged of an alloy steel with great strength as one body which integrates field core, yoke and shaft. A field coil is placed in the groove. Direct current is conducted through the coil to produce magnetic flux.

The short-circuit ratio for the generator is as low as 0.6 to 0.8. Its rated voltage commonly used is 12 to 25 kV. Presently, generators of 66 to 1,000 MW are being operated.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG13-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Generator and Station Electric Equipment (2)			

2. Cooling System for Generator

Turbine generators rotate at high speeds and have a small capacity. Therefore, they generate a large quantity of heat and require a hydrogen-cooled or water-cooled system.

Two systems are used: indirect (normal) cooling system which retrieves the quantity of heat generated in the coil via an insulating material and direct cooling system with a coil having the structure through which a cooling medium is conducted for retrieving the quantity of heat. In general, stators are cooled in an indirect hydrogen-cooled system, a direct hydrogen-cooled system or a direct water-cooled system. Rotors are cooled in an indirect hydrogen-cooled system or a direct hydrogen-cooled system.

Demineralized water mixed with an ion exchange resin is used as the cooling medium. The properties of various cooling mediums.

(1) Characteristics of hydrogen-cooled system (compared with air-cooled system)

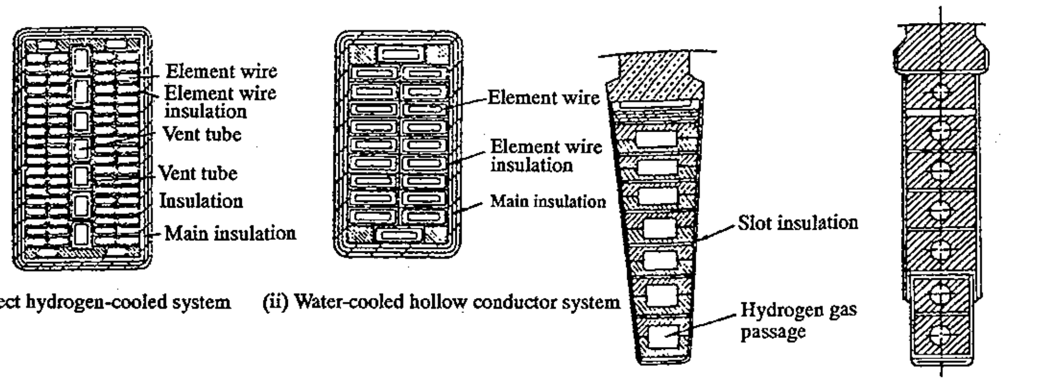
1) Hydrogen has a specific heat 14 times that of air. It has an excellent cooling effect. Higher pressure of filled hydrogen will result in a greater effect. (In general, a pressure of between 0.1 and 0.4 MPa is used.)

2) Hydrogen's specific weight is approximately 7% of that of air under the same pressure. Hydrogen's windage loss is roughly one tenth.

3) Less frequency of occurrence of corona discharge enables the equipment to be operated longer.

Remarks	Revisions	
	2003/Nov.	Original

3) Less frequency of occurrence of corona discharge enables the equipment to be operated longer.



(i) Direct hydrogen-cooled system (ii) Water-cooled hollow conductor system

(i) Hydrogen-cooled system (ii) Water-cooled system

(a) Section of fixed coils (b) Section of rotor coils

Structure of coils in turbine generator

4) A hydrogen-cooled system emits less noise during operation than an air-cooled system. It should be noted that hydrogen whose purity falls in the range between 4 and 70% is liable to explode. For this reason, the hydrogen must be maintained over 95% in the generator. As a protective measure, a bearing seal oil system is installed to prevent the hydrogen gas from leaking along the generator shaft.

(2) Indirect cooling and direct cooling

Indirect cooling uses hydrogen gas that passes over the insulation of the coils. In order to raise the generator's output, the pressure of the hydrogen gas can be increased to increase the surface heat conductivity and thus the cooling effect. However, there is a limit to this measure; it is generally taken for generators of 175 to 200 MW.

A direct cooling system is adopted for generators of larger than 200 MW. With a direct cooling system, the current density of the coils can be raised. Use of demineralized water in place of hydrogen gas will lead to an output 2.4 times the level achieved by the latter.

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG14-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Station Electric Energy (1)			

Station electric energy is a generic name for all kinds of electric energy required for activating the auxiliary (ancillary) equipment for operating boilers, turbines and generators and for activating automatic control systems, computers and lighting equipment. In general, station electric energy is several percent of the generator's output. Station electric energy is used after the step-down process in the station transformers (unit transformers) to meet the consumption requirements in specific auxiliary equipment.

(1) Metal clad

A metallic box assembly of more than ten distribution panels for 3 to 6 volts which *incorporate circuit protection and* switching devices and which are metal-clad for each feeder. A metal clad is capable of supplying a total of electric energy of more than 100 kW *to the entire auxiliary equipment.*

(2) Power center

A power center is sometimes referred to as a load center. It supplies 460 V of power to auxiliary equipment of a total of several tens to hundreds of kilowatts. A power center is installed around the center of various auxiliary devices. This is also a metallic box assembly of distribution panels incorporating circuit protection and switching devices.

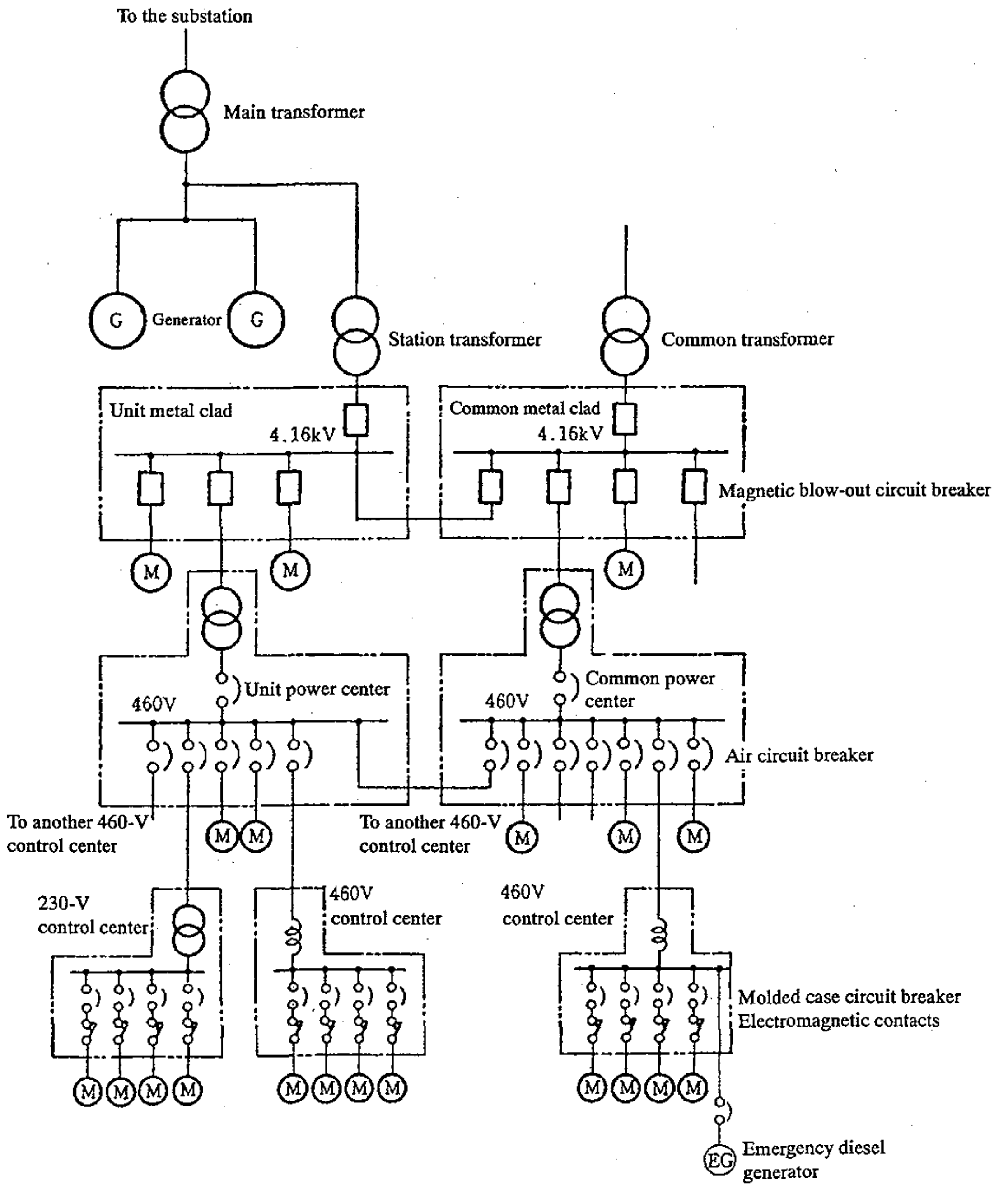
(3) Control center

This is also referred to as a load center. It supplies 220-V power to auxiliary devices of less than several tens of kilowatts. Like a power center, a control center is a cubic assembly of distribution panels located around the center among these auxiliary devices installed in several groups.

The group of auxiliary devices to which an emergency oil pump required for safe stopping of the unit is connected has a feature that allows this group to receive the power generated by an emergency diesel generator that is activated in case of loss of the station power source.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG14-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	**Station Electric Energy (2)**			



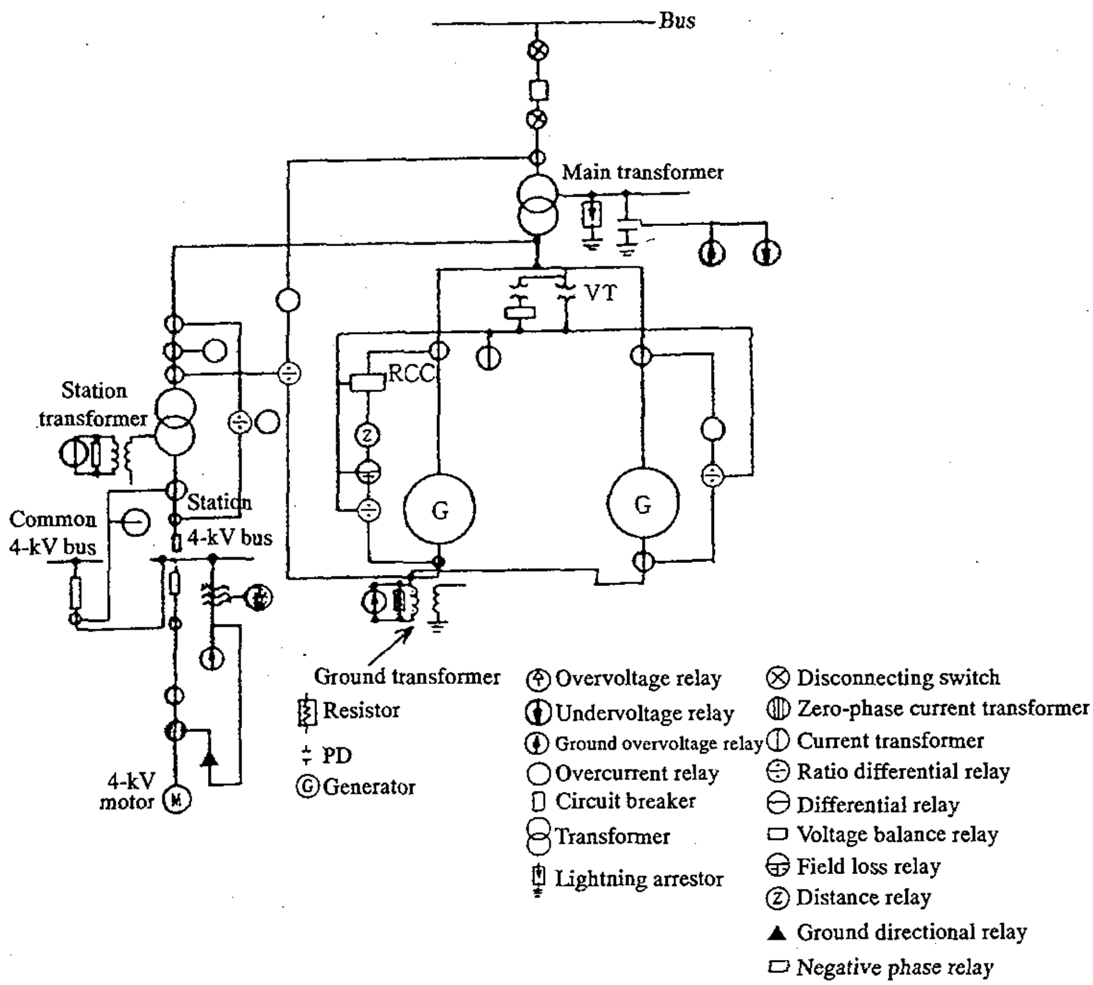
One-line diagram for station electric energy

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG15-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	**Protective Devices for Turbine Generator and Electric Equipment (1)**			

(1) Protection of generator and main transformer

If an accident occurs in the generator or in the main transformer, disabling safe operation, the protective relay is activated to stop the unit.



Protection of generator and main transformer

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG15-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Protective Devices for Turbine Generator and Electric Equipment (2)			

1) **Protection of generator**

(a) Ratio differential relay: same for hydraulic turbine generator;

(b) Excessive current relay: same for hydraulic turbine generator;

(c) Neutral point ground excessive current relay: same for hydraulic turbine generator;

(d) Excessive voltage relay: same for hydraulic turbine generator;

(e) Field loss relay: activated to protect the generator when the excitation in the generator drops considerably, which may cause system disturbance;

(f) Negative phase relay: activated to protect the generator when the load becomes unbalanced for the three phases and when the inverted phase current flowing through the armature winding becomes smaller than the limit value.

2) **Protection of main transformer**

(a) Ratio differential relay with higher harmonics limiter: thanks to the capability of protection and harmonics limitation in case of short-circuit in the windings, this relay is not liable to incorrect operation due to a no-load turn-on current in the transformer;

(b) Ground excessive voltage relay: protection in case of ground accident in the windings at the high-voltage side;

(c) Excessive current relay: protection when the current exceeds the specified value in the windings.

(2) Protection of station transformers

1) **Ratio differential relay:** protection in case of short-circuit in the windings;

2) **Ground excessive voltage relay:** protection in case of grounding in the windings.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG15-3
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Protective Devices for Turbine Generator and Electric Equipment (3)			

(3) **Protection of induction motors**

1) **Excessive current relay:** protection in case of short-circuit in the windings or when the current exceeds the specified value in the windings;

2) **Directional ground relay:** protection when a grounding occurs in the windings.

(4) **Protection of station circuits**

1) **Ratio differential relay:** protection of the bus against excessive current;

2) **Ground relay:** protection of the bus when a grounding occurs.

Remarks	Revisions	
	2003/Nov.	Original

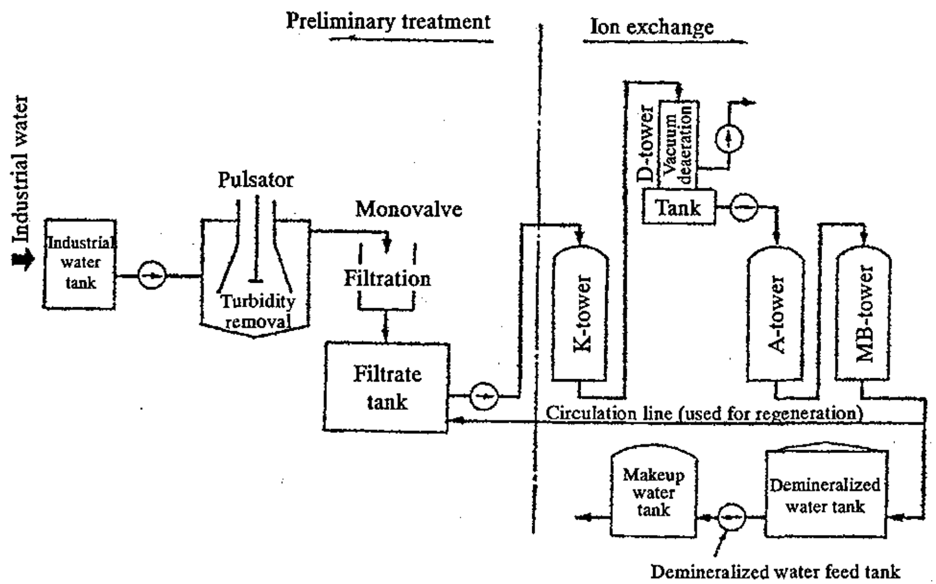
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG16-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Water Treatment Equipment (1)			

(1) Water treatment equipment

A thermal power station has primary water treatment equipment for automatically converting industrial water into demineralized water as boiler makeup water and secondary water treatment equipment for mainly adjusting the pH value of the water in the feed water line. Deteriorated water in the boiler will adversely affect the evaporation tubes, the superheaters and the turbine blades. The management and control of the water quality is of great importance.

1) Primary water treatment equipment

The components of primary water treatment equipment.



Primary water treatment equipment

(a) Preliminary treatment: The amount of coagulant to be added is automatically controlled depending on the flow rate of the industrial water. Turbid matters and colloidal substances in the water are precipitated in the turbidity remover. The supernatant liquid is filtered to remove floating solids. Filter elements are cleaned by backwashing.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG16-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Water Treatment Equipment (2)			

(b) Ion exchanger: Filtered water is transferred to the K-tower where Ca and Mg are removed from the water and the resulting water is sent to the D-tower where bicarbonates are eliminated. The water thus processed is then sent to the A-tower and MB-tower where its purity is enhanced. The resulting demineralized water is stored in the demineralized water tank.

2) Secondary water treatment equipment

This equipment controls the pH value of the water that may affect the protective film on the surfaces of the iron evaporation tubes.

(2) Makeup water system

This system compensates for the loss of water (1 to 3%) during circulation through the water/steam line. When the level of the water in the condensate tank on the condenser becomes lower than the specified limit, this system is automatically activated to feed an appropriate amount of water from the demineralized water tank into the condensate tank.

(3) Feed water pump

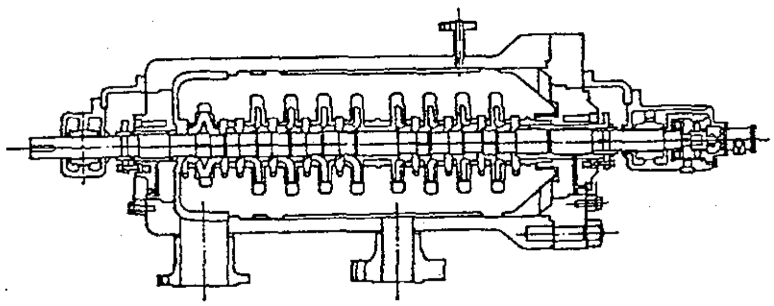
An accident in the pump may result in serious damage to the surrounding equipment. A thermal power station always has a reserve pump installed. In case of failure in the main pump, the line is automatically switched to the reserve pump for uninterrupted water feed.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG16-3
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Water Treatment Equipment (3)			

1) Type of pump

Industrial thermal power stations usually use the barrel type multistage centrifugal feed pump. This type of pump is suitable for coping with possible deformation of the casing due to high pressures and high temperatures. The feed water pumps recently used for large-capacity high-pressure, high-temperature boilers have a greater length required for incorporating an increased number of blades. Some of these pumps are sized in smaller dimensions and are capable of working at higher speeds.

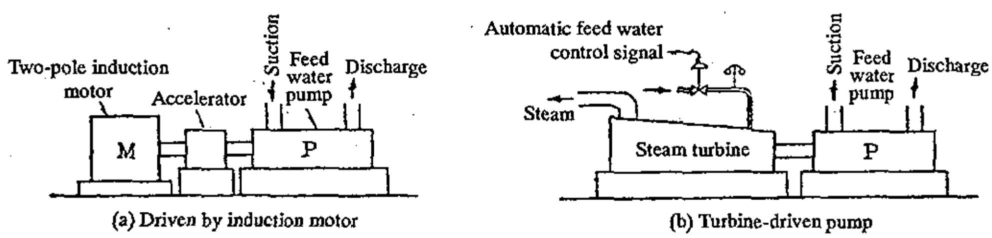


Barrel type multistage centrifugal feed pump

2) Driving mechanisms for pump

(a) Induction motor
A combination of a two-pole induction motor and an accelerator is usually used for pumps of output of less than 265 MW.

(b) Turbine
An independent steam turbine is directly connected to a high-speed pump. A desired rotating speed can be selected for the turbine. This combination is usually used for the equipment of 350 to 600 MW.



Driving mechanisms for feed water pump

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.TG17-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Feed Water Heater (1)			

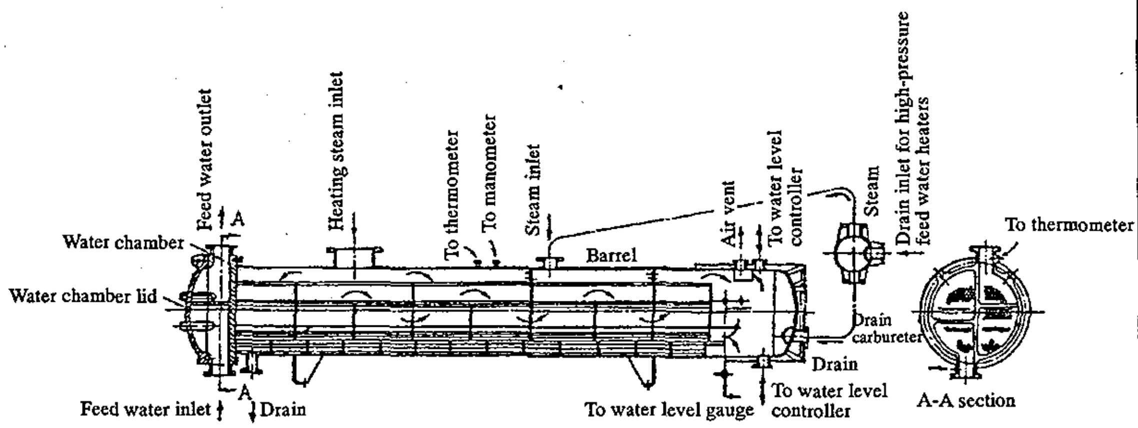
(5) Feed water heater

In general, heaters at the suction side of the feed water pump are referred to as "low-pressure feed water heaters" and those at the discharge side as "high-pressure feed water heaters." A feed water heater consists of a barrel, heating tubes and a water chamber. The barrel is made of steel plates of variable wall thickness depending on the pressure handled. Couplings and steam and feed water nozzles are welded on the barrel. Two types of feed water heaters may be used: a horizontal type often used for the low-pressure side and a vertical type often used for the high-pressure side. The feed water flows through many heating tubes, absorbing the heat, and comes out of the outlet. The bleeding-heating steam flows into the barrel of the heater, providing the feed water with latent heat (heat of evaporation), and flows out as saturated water. Under natural gravitation, this saturated water flows into the heater on the upstream low-pressure part where it evaporates under the differential pressure, and heats the feed water together with the extracted steam. Thus, the resulting water is finally transferred to the deaerator on the high-pressure feed water heaters, or to the condensate tank of the condenser on the low-pressure feed water heaters, and is then mixed with the feed water.

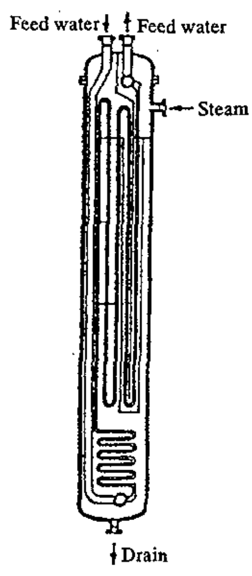
In general, only one line of feed water heaters is used for a power station of smaller than 175 MW, but two lines of heaters are used for a power station of larger than 265 MW. With a large turbine, seven to nine bleeding stages are used for heating the feed water.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG17-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Feed Water Heater (2)			



(a) Low-pressure feed water heater



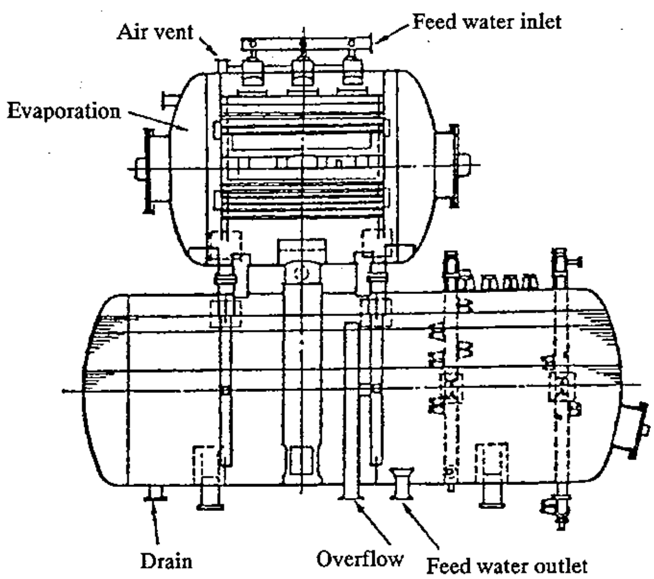
(b) High-pressure feed water heater

Feed water heaters

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.TG18
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Deaerator			

A deaerator is a device that heats the feed water up to higher than the saturation temperature to separate and discharge O_2 and CO_2 contained in the feed water in order to reduce the dissolved oxygen in the feed water to less than 0.05 cc/l. A deaerator has the tray structure. This deaerator can be referred to as a mixing heater in which steam and feed water flow down in the deaerator and directly come into contact with each other. The water tank under the deaerator has a capacity for the maximum flow rate of feed water for 10 to 20 minutes. The flow rate is controlled depending on the changing load.



Tray type deaerator

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG1-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Internal Combustion Engine (1)			

There are two kind of Internal combustion generator, internal combustion generator and Gas turbine generator. There no need to equip steam generator like Thermal power plant and it has high efficiency.

Diesel power plant

Out line of the equipment of Diesel plant

(1) Main engine

Main parts of these are Cylinder, Crank, Cam, Valve, Flywheel,

(2) Fuel equipment

Supply oil to Cylinder, Oil Tank, Strainer, Oil-Pomp, and Injection valve.

(3) Exhaust equipment

Consist of Exhaust manifold, Silencer and so on.

(4) Supercharger

Supercharge the air to Cylinder. Most type is Exhaust gas drive. It can increase power 50%-100%

(5) Cooling unit

Cooling unit controls main engine temperature.

(6) Lubricating oil

Consist of oil tank, oil pomp, oil cooler, oil pipe and oil strainer.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DG1-2
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG1-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Internal Combustion Engines (2)			

Engine Classification

Engines may be classified in many ways according to their basic cycle and physical components. Thermodynamically they may be classified according to the combustion process:

(1) constant volume- Otto cycle;

(2) constant pressure- diesel cycle;

(3) combination constant volume and constant pressure;

From the design standpoint engines may be classified as follows:

1. Piston strokes per cycle

1) Two
2) Four

2. Fuel used:

1) Gasoline
2) Gas
3) Oil
4) Gas and oil combined

3. Ignition method:

1) Spark-ignition
2) Compression-ignition
3) Surface-ignition

4. Fuel admission:

1) Injection(air blast or mechanical)
2) Carburetor
3) Mixing valve
4) Compression(for gaseous fuels)

5. Air admission:

1) Simple aspiration (four- stroke cycle)
2) Scavenging by blower or pump(two-stroke cycle)
3) Supercharging (two- stroke and four- stroke cycle)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Characteristic of Diesel Engine			

General Characteristic

(1) Selection free from the location condition and it is possible to install easily.

(2) Easy to start and stop operation

(3) Heat efficiency is about 35%-40% and quick response of load change.

(4) It is not suitable for large power plant and there is limited capacity.

Other Characteristic (compare to steam thermal power plants)

(1) Quick start.

(2) Use little cooling water (because there is no steam condenser)

(3) High efficiency

(4) Not necessary too wide space.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DG3-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Diesel Power Station (1)			

Main Components

A diesel power generation station consists of the components.

(1) Diesel engine

Generates torque. It is composed of a cylinder, a piston rod, a crank shaft, a cam shaft, a valve assembly and a flywheel.

(2) Fuel unit

Feeds fuel oil to the cylinder. The fuel unit is composed of a fuel oil tank, a fuel oil filter, an injection pump, an injection timer, and injection valves.

(3) Exhaust gas unit

Discharges the exhaust gas from the cylinder to the atmosphere. The exhaust gas unit is composed of an exhaust gas manifold, an exhaust gas pipe and a silencer.

(4) Supercharger

Charges the cylinder with additional air (supercharge). Superchargers used in a diesel power station are usually based on an exhaust-gas-driven mechanism. It increases the engine output by 50 to 100%.

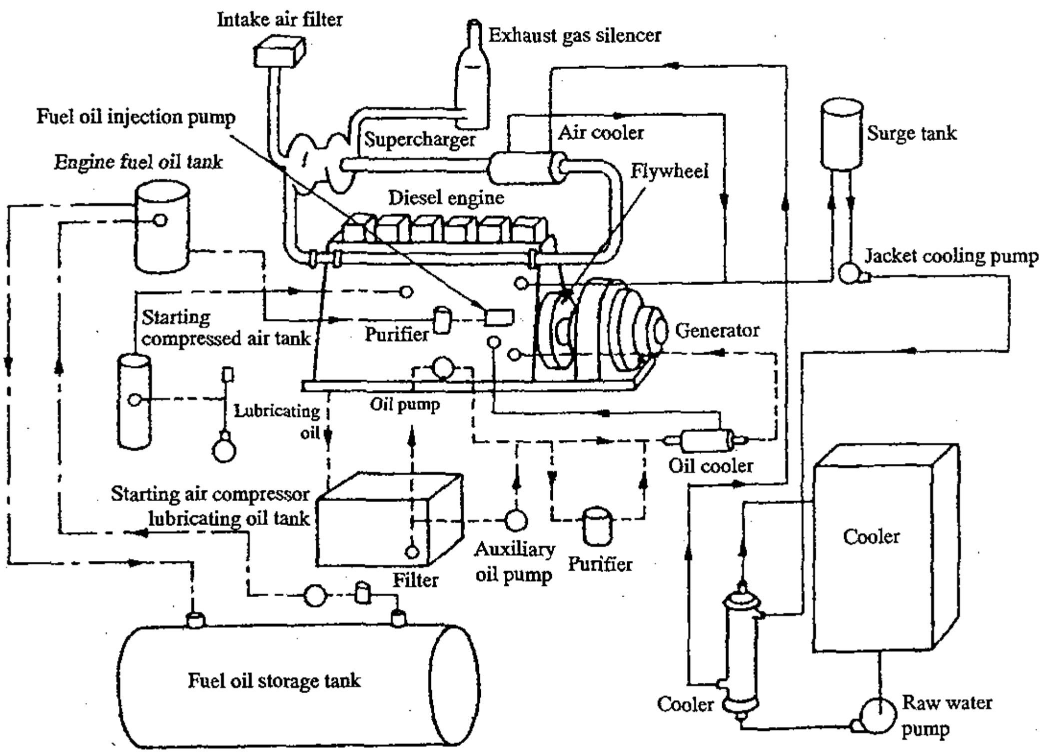
(5) Cooling system

Cools the cylinder and the combustion chamber to maintain the engine's temperature at the optimal level (about 65°C). A pump is used to feed the cooling water to the water jacket provided around the engine.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG3-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Diesel Power Station (2)			

(6) Lubrication system



Diesel power station

Feeds lubricating oil to the crankshaft, the connecting rod and the cam shaft. The lubrication system is composed of an oil tank, an oil pump, an oil cooler, an oil filter and a feed oil pipe.

The flywheel contributes to a smooth and steady revolution for the engine.

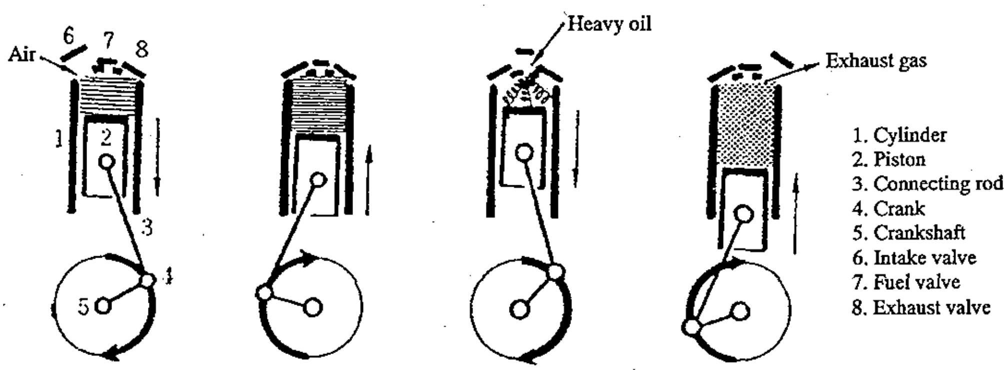
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.TG4-1**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	**Diesel Engine (1)**			

(1) Operation strokes of diesel engines

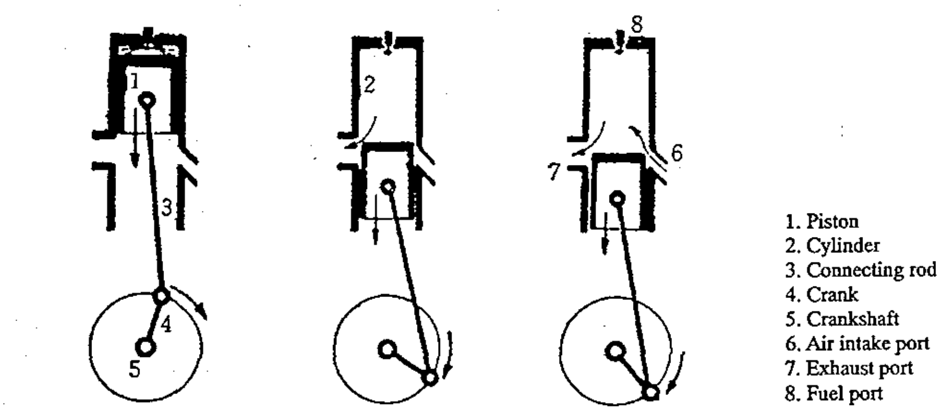
Two types of diesel engine are available: 2-cycle engine and 4-cycle engine. The strokes of a 4-cycle diesel engine. A 4-cycle diesel engine is an engine in which one explosion occurs while the piston makes two upstrokes and two downstrokes. The strokes of a 2-cycle diesel engine. With this type of engine, one explosion occurs while the piston makes one upstroke and one downstroke. Motive power is only generated during the explosion stroke. During the compression stroke, the motive power is consumed.

A number of cylinders are used to eliminate any non-uniform revolution.



(a) Intake stroke (b) Compression stroke (c) Explosion stroke (d) Exhaust stroke

Operation of a 4-cycle diesel engine



(a) Compression/explosion stroke (b) Exhaust stroke (c) Intake stroke

Operation of a 2-cycle diesel engine

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG4-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Diesel Engine (2)			

(2) Choice between 2-cycle engine and 4-cycle engine

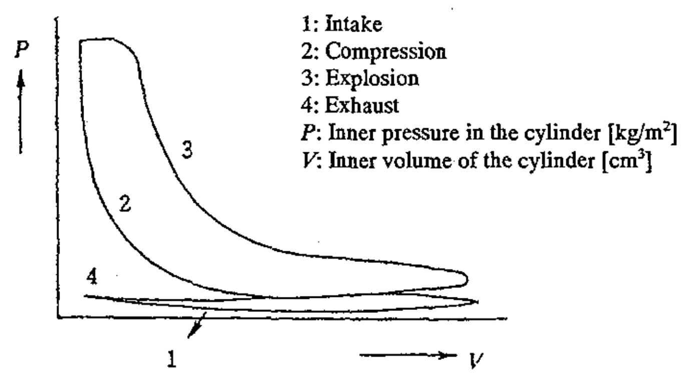
2-cycle diesel engines are operated at lower speeds than 4-cycle diesel engines. Therefore, the former have lower efficiency than the latter. In general, 4-cycle diesel engines are used in thermal power stations.

(3) Cylinder configurations and fuel oil injection systems

For engine cylinders, one of two configurations is adopted: an in-line configuration or a V-shaped configuration. Most thermal power stations have adopted airless injection engines where a supercharger directly applies a high pressure ranging from 10 to 50 MPa to the fuel oil to inject it into the combustion chamber.

(4) Characteristics of diesel engine

An indicator diagram for a diesel engine. The indicator diagram is a graphic representation of the cylinder pressure as function of the piston's position in the four strokes of a 4-cycle diesel engine. The area formed by the line on the diagram represents the amount of work accomplished.



Indicator diagram for a diesel engine

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DG4-3
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Diesel Engine (3)			

1) Equation for determining the indicated horsepower of a 4-cycle engine

$$P = \frac{P_m \times A \times L \times N}{2 \times 75 \times 60} \text{ [PS]} \quad \text{(2-1)}$$

where P_m: average effective gas pressure in the cylinder [kg/cm^2]; A: sectional area of the piston [cm^2]; L: stroke of the piston [m]; N: rotating speed of the piston [rpm].

2) Equation for theoretical efficiency η_c (ideal indicator diagram for 4-cycle diesel engine)

$$\eta_c = 1 - \left\{ \frac{K^{k-1}}{kR^{k-1}(K-1)} \right\} \quad \text{(2-2)}$$

where K: v/V, v being the inner volume of the cylinder upon completion of a compression and V being the inner volume of the cylinder upon completion of an expansion; R: compression ratio; k: constant-pressure ratio / constant-volume ratio = 1.41.

3) Measures for enhancing efficiency

Various measures can be taken to enhance the efficiency of a diesel engine: (a) increase the compression ratio, (b) improve the air feed, (c) install a supercharger, (d) improve the scavenging during the intake stroke.

Remarks	Revisions	
	2003/Nov.	Original