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Fwd'd to: Mr. Suzuki(?)

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Identify technologies and methods for the reduction of energy losses and recommendation of ways to foster in-house awareness.

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1. Introduction and Background

1-1 Significance of Energy Conservation

(1) Strengthening the Energy Supply and Demand Structure

Following the two oil shocks, the development and introduction of oil-substitute forms of energy devised by various countries around the world, including Japan, and their efforts at promoting energy conservation, have borne fruit, and in recent years international oil supply and demand has shown signs of moderating. Of late, however, oil demand has been increasing steadily against a background of world-wide expansion in business activity. It is believed that the degree of dependence on OPEC will rise during the 1990s owing to this steady increase in the demand for oil, centring on the developing countries, and a decrease in the production capacity of the non-OPEC oil producing countries, leading to the destabilization of oil supply and the tightening of oil supply and demand. It has been forecast that this may result in a rise in the price of crude oil.

The proportion of energy consumed in the world today is oil-38%, coal-30%, natural gas-20%, hydro power-7%, and nuclear power-5% (BP statistics). Of these, the fossil fuels, which account for the highest percentage, are a finite resource. In particular, the proved reserves of oil, the most convenient of the fuels, are only expected to last another forty years. It is an important responsibility of our generation to use these limited energy resources effectively and without waste so that they can be passed on to future generations.

Since the developed countries, which only account for slightly more than 20% of the world's population, are currently more than 60% of the total amount of energy consumed in the world, the developed countries must seize the initiative and tackle the issue of energy conservation.

(2) Contributing to the Reduction of the Environmental Burden

In recent years there has been increasing concern about global warming due to a rise in the concentration of CO_2 caused by the burning of fossil fuels, and international organization have begun examining ways to counter this environmental threat.

We are awaiting the further accumulation of scientific knowledge regarding the problem of the 'greenhouse effect', however most discussion carrried out in the international organizations focus on controlling the amount of CO_2 released through energy consumption by promoting both energy conservation and sources of energy that release less CO_2. At the Summit of Arch held in July 1989 it was agreed that increasing energy efficiency could make substantial contributions to reducing the emission of greenhouse gases, and the economic declaration urged international organizations concerned to encourage measures, including economic measures, to improve efficiency in the use of energy. In this way, the promotion of energy conservation from the viewpoint of contributing to the reduction of the environmental burden is becoming a common goal throughout the world.

1-2 Progress in Energy Conservation and Medium and Long Term Issues

(1) Japan's Achievement in Energy Conservation

With the two oil crises as the turning-point, Japan has been tackling the issue of energy conservation through the joint efforts of the government and the people. Coupled with industrial restructuring, these energy conservation measures have seen a 36% improvement in Japan's energy consumption against GNP basic unit between fiscal 1973 and fiscal 1987 (Fig.1.1,Table 1.1). If the energy consumption against GNP basic unit for 1987 were the same as the basic unit for 1973, it is estimated that the amount of energy consumed would have been the equivalent of 690 million kl of crude oil. When compared with the actual amount of energy consumed (443 million kl), it shows that energy conservation equivalent to 250 million kl was achieved.

Furthermore, if we use the energy consumption against GDP basic unit to compare the state of energy conservation in Japan with that of other countries, we can see that Japan's rate of improvement is the highest among the developed countries (Fig.1.2).

(2) State of Energy Conservation in Industrial Sector

In Japan energy conservation has, to date, been actively promoted centring on the industrial sector, particularly the manufacturing industry, which is a major energy consumer, and has been advanced to a considerable degree in virtually all industries. Looking at the changes in the energy consumpion basic unit (1973 standard) of the major industries, we can see that each manufacturing industry had recorded a 20-40% improvement by 1987 (Fg.1.3). The amount of energy conservation during fiscal 1987 is estimated to be the equivalent of 51 million kl of primary energy crude oil.

The degree to which energy conservation is promoted in Japanese industry is thought to be the highest in the world, and the energy consumption basic unit of other developed countries is 1.2-1.4 times that of Japan in the iron and steel industry, and 1.5-1.6 times in the cement manufacturing industry (Fig.1.4,1.5).

2. Energy Conservation in Industrial Sector

Industries of Japan, which continued rapid growth under the supply of low-priced petroleum during the 1960's, made efforts in pursuit of energy saving measures after the oil crisis experienced in 1973, and such efforts together with administrative measures which supported energy conservation have achieved a great success.

This section will explore the trends in energy consumption in Japan's high-energy-consuming industries having an important influence on the nation's total fuel consumption. The methods that these industries have been taking to conserve energy are reported below.

2-1 Iron and Steel

Accounting for nearly 15% of the total energy consumption in Japan, the iron and steel industry is currently one of the most active investors in energy conservation measures. The ratio of energy conservation investments to the total for investments by this industry is consistently high at about 20%. The total amount of funds devoted to energy conservation is also on the increase.

The enthusiasm with which the iron and steel industry has tackled the problem of energy conservation has resulted in a clear reduction in its substantial energy consumption rate (Fig.2.1.1).

Energy conservation has therefore been making headway in the iron and steel industry. Since iron and steel plants consume vast quantities of energy at high temperature in the production process, they are expected to be successful in their efforts for further energy conservation through many methods including the discovery of methods to improve their production processes and recover waste heat. If energy conservation measures are taken in the industry from now on, the coefficient of effective energy utilization which now stands at about 50%, will be increased to about 65%. The following is a brief summary of the chief energy conservation measures being taken at present.

(1) Blast Furnace Top Pressure Recovery Electricity Generation Equipment

When a blast furnace is used for melting iron ore to make pig iron, hot air is blown in by compressor to highten the pressure at the top of the furnace. This is performed in order to economize on fuel and enhance productivity. Except for a small part that was used to blow away fine particles of dust, the energy from the heightened pressure used to be released almost directly into the atmospher(Fig.2..1.2). In blast furnace top pressure recovery electricity generation, the pressure energy is not lost but recovered to rotate a gas turbine (top pressure recovery turbines(TRTs)) to generate electricity(Fig.2.1.3,2.1.4).

(2) Continuous Casting Equipment

When molten steel is cast by conventional methods, a complicated series of steps involving melting the steel, making ingots, soaking and blooming is required. A new process has been developed to eliminate the need for many of these procedures. In this new process called continuous casting, molten steel is poured directly from a nozzle into a mold. The steel is then shaped by rollers into the desired form while it is slowly cooled.

(3) Dry Quenching of Coke (Coke Dry Quenching(CDQ))

Conventionally, red-hot coke produced by the carbonization of coal is quenched by sprinkling it with water, and the heat energy of the hot coke is released into the atmosphere. In dry quenching, red-hot coke is quenched with inert gas instead of water, and the heat energy of the coke is recovered in the form of steam which is then utilized for various purposes at iron mills(Fig.2.1.5).

(4) Converter Gas Recovery Equipment

A pure oxygen converter discharges carbon monoxide and other high-temperature gases in the refinement process. A method is now in use in which the heat of the discharged gas is recovered and used as a source of energy.

(5) Direct Rolling

Bloomed and rolled steel used to be cooled for the inspection and repair of surface flaws, and was then reheated in the furnace and conveyed to the rolling equipment. In direct rolling, this cooling is omitted and the steel is inspected and repaired while still hot, thus conserving energy that would have had to be used in reheating (Fig.2.1.6).

2-2 Cement Industry

The cement industry is one of Japan's typical high energy consumption industries. The ratio of energy costs to all production costs being more than 50%. Almost all of the improvements to the production technology in this industry up till now have aimed at the conservation of energy and by the introduction of a series of energy conservation measures, the total energy consumption rate in the cement industry has dropped steadily year by year.

Cement production involves the following main processes:

a) the preparation of raw materials through the drying of limestone, clay, silica, slag and other raw materials

b) finely pulverizing and blending them

c) baking them to that the blended raw materials are heated to semi-molten state (about 1,450 C)

d) quenching to make the intermediate product of clinker

e) finishing whereby the clinker is mixed with plaster and finely pulverized

(1) Improving the Thermal Efficiency

Heat consumption was 1,700 kcal/kg in 1955 but it had decreased to less than half of that, or 710 kcal/kg by 1988. Energy savings have been accomplished through various measures in the production process, such as improving heat recovery from the clinker cooler or improving heat-exchange efficiency in the preheater cyclones. However, changing the type of kiln made a significant contribution to this reduction. Kilns were changed from dry or wet type with exhaust-gas-utilizing boiler, to wet long killns, on to semi-wet kilns, and finally to SP and NSP kilns. This transition of kiln process is shown in Fig.2.2.1.

(2) Using NSP Kiln with DD Furnace

Fig.2.2.2 shows the gas and material flow for an NSP kiln with DD furnace. The DD furnace is divided into four zones, according to specific function (Fig.2.2.3).

a) Reducing zone (Zone 1)

This is the inverse conically shaped part at the lower side of the DD furnace, whose main function is to reducce NO_x in the kiln exit gas.

b) Fuel cracking and burning zone (Zone 2)

This is the cylindrical part of the central lower side of the DD furnace, whose main functions are to vaporize, crack and partially burn the fuel injected into this oxygen-rich zone.

c) Main burning zone (Zone 3)

This is the part up to the orifice at the central part of the DD furnace, whose main functions are to burn fuel and to transfer generated heat to the raw materials.

d) Complete burning zone (Zone 4)

This is the top cylindrical part of the DD furnace, whose main functions are to burn the remaining fuel gas and to accelerate calcination of the raw materials.

The DD furnace throat which connects directly to the upper kiln feed end housing passes the kiln's exit gas and create a first-stage raw material spouted bed with the upward-blowing kiln gas stream.

In addition to the general features of its precalcining system, the DD process offers the following advantages.

a) Reduced power consumption

Pressure drop in the DD furnace is remarkably lower than that of any other process, because the gas and raw material are mixed not by swirl motion of the gas, but by the cross gas flow from the kiln and the cooler. As a result, power consumption of the waste gas fan can be reduced.

b) Reduced coating trouble

The DD furnace is installed above the kiln feed end housing and the kiln gas is fed directly into the furnace without passing through the rising duct. As a result, coating trouble which is most likely to develop in the kiln gas rising duct is eliminated, ensuring stable operation.

c} Reduced clogging trouble

The kiln gas feed into the DD furnace is evenly mixed with combustion air from the cooler and raw material from the third-stage cyclone. Then the conglomerate mass forms a combustion zone of fuel blown in from the face of the furnace cylinder. As a result, local overheating inside the furnace is prevented and there is no worry about a coating being formed (Fig.2.2.4). Even if coating should happen to develop in the furnace and peel off, it cannot cause clogging in the furnace because the bottom of the furnace is connected to kiln feed end housing by a large-diameter opening.

d) Reduced after-burning trouble

After-burning space is provided in the DD furnace so that, when the fuel and gas are thoroughly mixed, complete combustion can take place. This prevents any unburned gas from entering the bottom cyclone and causing damage to the equipment, heat loss or clogging troubles due to after-burning (Fig.2.2.5).

e) Reduced NO_x in exhaust gas

In the DD process, fuel is infected into the kiln gas fed in from the bottom opening of the DD furnace, creating a deoxidizing atmosphere. With the raw material as a catalyzer, it functions in such a way as to deoxidize NO_x in the kiln gas. Thus the volume of NO_x in the exhaust gas of the DD furnace can be reduced even further.

2-3 Synthetic Fiber

Synthetic fibers can be classified into two kinds: One includes rayon, acetate, etc. that are produced by chemically treating natural cellulose, and the other is synthetic produced by synthetic reaction from chemical materials. Synthetic fibers range widely from nylon to polyester, polyacrylnitrile, and polyvinyl alchol.

Polyester, which is one of the most important synthetic fibers in the world, is produced by the process shown in Fig.2.3.1.

Terephtalic acid and ethylene glycol are heated and polymerized. Because this polymer contains water-soluble unreacted substances, it is extruded into a string in water to solidify, cut into chips, and then cleaned using hot water. The chips are dried and sent to the spinning machine, where they are melted and extruded through the small hole in the spinneret. The polymer out of the spinneret is cooled in the air to solidify in fiber form, and then is wound as yarn. The yarn is stretched 3 to 4 times to rearrange the molecular orientation and increase the strength.

The unreacted substances that were extracted into the hotwater are condensed and cleaned of impurities in the evaporation tower and distillation tower to be used again as material.

As described, the process till the material enters the spinning machine are similar to those of the chemical industry, and employ fluid-handling equipment consisting of towers, tanks, pipes, and pumps, ans solid-handling equipment consisting of a dryer, centrifugal separator, etc.

Because these sets of equipment handle organic compounds and must be kept free of local overheating, a jacket steam heating system is mainly used. Heating medium oil and electric heaters are also used in part of the processes. The utilities facilities include boiler and air conditioning chillers for the spinning process.

The utilities used in each of the processes are shown in Fig.2.3.1.

(1) Energy Consumption

The kinds of energy used in the polyester production process are shown in the process diagram of Fig.2.3.1.

In producig synthetic fibers, monomers are polymerized into macro-molecules as material. The polymerization process consumes much energy for heating, stirring, and pressure reduction to polymerize the monomers; cooling, washing, and drying the macro-molecules produced, and recovering unreacted monomers. Steam, used as heat source, is generated by a back-pressure extraction turbine driven by an independent generator set, and is used for many purpose: for heating in the production process; for driving the boiler forced draft fans and feed water pumps; for quenching yarn driving the turbo refrigeraetor for air conditioning the spinning room; and as a heat source for absorption refrigerating machines. That is, steam is used for these different purposes according to different levels of pressure.

Synthetic fiber production versus energy consumption in Japan is shown in Table 2.3.1.

Compared with the reference year of 1973, the year 1988 was up 4.4% in production, down 81.2% in electric power consumption, and down 26.5% in fuel consumption. Fuel oil consumption shows tendencies of declining further.

(2) Energy Conservation Measures

Important points for energy conservation in prroducing chemical and synthetic fibers are shortening the proccesses, improving the heating and cooling patterns, rationalizing the equipment operating methods, introducing energy-saving machines and devices, recovering waste heat, and optimizing equipment capacity.

Table 2.3.2 shows the main energy conservation measures that have been taken so far in Japan.

The basic procedures for implementing energy conservation measures and their effects are discussed below in a case study of generating equipment.

1) Boiler combustion control, etc.

2) Minimizing heat loss

The manufacturing process up to melting is simiar to that used in chemical plants. A large number of towers and tanks are connected to one another with pipes, and the object is heated to 100 to 300 C by a heating medium. It is important, therefor, to prevent heat loss from the surfaces of these constituents of the process. Generally, the main equipment itself is well-insulated, but the flanges and end pipes small in diameter tend to be left uninsulated, or improperly insulated.

3) Use of flashed steam

High pressure steam is used in some part of the process to heat to high temperature. Its condensate should be returned to the flash tank to generate low-pressure steam and make effective use of it.

4) Condenate recovery

5) Use of back-pressure steam

In applications where steam of different pressure is used, steam of different pressures is generated using two or more boilers, or a high-pressure boiler is used to generate steam, and part of it is reduced using a valve. If high-pressure boilers only are used and if a steam turbine is employed in place of the reducing valve to generate electricity with its motive power, electricity can be efficiently cbtained.

Factories using the above system have been increasing because small-sized efficient turbines have become available.

2-4 Paper and Pulp

The flow of the paper making process is shown in Fig.2.4.1. In order to make wooden fiber sheets, the fiber is carefully selected and beaten in preparation procedures, and is gradually dehydrated in uniform dispersed condition. In the final stage, moisture approximately twice as much is evaporated by steam. This paper making industry is a large-scale equipped industry. In addition to electric power for driving the equipment, this industry uses 500 to 1,000 tons of water per ton of paper. Also an enormous amount of electric power is required for moving this water. This is one of the reasons why the paper making industry is an energy intensive industry.

(1) Energy Consumption

The places at the paper mill where energy is consumed are as shown in Table 2.4.1. Almost all the majority of thermal energy is consumed in the dryer part excepting the pulp manufacturing section. As only an exception, some paper miills were using steam for the purpose of drying after coating in the continuous paper-making and coating unit, and for pulper to promote the defiberizing and to accelerate beating and fibrillation caused by swelling of the fiber. Electric energy is used as rotary power for the rotor or the impeller which directly acts on the fiber in defiberizing, beating, circulation, stirring, and cleaning of raw materials. It is also used as rotary power for the cylinder for washing filter, dryer, etc. and transportation power for water, and raw materials. The process is divided into two part: the preparation of raw materials and the paper machine.

In the preparation parts at the paper mill without a pulp manufacturing section, direct thermal energy consumption is at a low level. Steam is only used for heating the pulper for used paper disintegration, dye dissolution and the glue making from starch at the printing paper mill. This steam consumption is very little, compared with steam consumption by the dryer. The energy consumed in the sheet formation process is almost entirely electric power and it is used for raw material transportation, raw material circulation in the chest, defiberization and beating. Most of this energy is converted to friction heat which in turn, increases the system temperature or is released into the atmosphere. Although it is not easy to control the release of this heat into the atmosphere, white water should at least be recycled and the aforementioned friction heat should be recovered to the maximum possible extent. Also the temperature drop by the use of fresh water should be prevented and the drying effect of the paper making process should be maximized.

The standard unit energy consumption rate of the paper making in Japan, is shown in Table 2.4.2.

(2) Energy Conservation Measures

1) Covering the cylinder by the hood.

Among the energy consevation measures in paper industry, the most effective one is management of supply and exhaust of air in the dryer part. If the best dried and high-temperature air is supplied into the surroundings of the dryer cylinder, and the high-humidity exhaust is rapidly ejected into the atmosphere, the drying efficiency will be improved.

The air discharged from the dryer part is at high humidity and, at the same time, is at high temperature (60 to 80 C). Therefore, if the heat is recovered in some way, the heat balance will be improved.

In order to achieve the above mentioned purposes, the hood covering the dryer cylinder group plays an important role.

In the ordinary paper machine, approx. 2 ton of moisture are evaporated for drying one ton of paper. For ejecting this vapor, 50 to 60 tons of air are required. Therefore, from the structural point of view, the following design considerations are given to the construction of the dryer hood.

a. The width of the hood and the height of the side wall should have sufficient dimensions for capturing wet air. In the case of the open hood, it is necessary that the height of the side wall is at least 2 m and the location is almost at 30 to 35 deg against the internal surface of the sole plate as the distance from the machine frame (refer to Fig 2.4.2). This must be done from the operational point of view to sufficiently blow off the vapor from the dryer pocket and let the ascending air current flow along the internal surface of the sole plate

The upper inclination is designed to prevent the dropping of condensed water in the interior. The upper space capacity should also be large enough

b. The location, size and shape of the exhaust port should be provided so that they can fully eject wet air without fail. At the same time the exhaust port should not make deflected air current which would be the case for uneven drying in the paper width direction.

In case the exhaust port is directly mounted to the hood ceiling, it should be provided at the portion equivalent to 3/4 of the wet end of the dryer part. This is because most of the vapor is generated in the so-called constant rate drying zone where the paper moisture is kept at about 15%.

c. The dryer hood should have such a structure that it does not disturb paper feed operation.

d. The hood should also be so designed as it allows easy access to the operator for the maintenance, repair and cleaning of the dryer.

e. Material for the hood should be water-proof, fire-resistant, and anti-corrosive.

f. The hood ceiling should be strong enough for the passage of the operator.

In the conventional paper machine, a roof-shaped hood was provided on the group of dryer cylinders and the hood was equipped with 3 to 4 pieces of large exhaust ducts for exhaust by natural ventilation.

For developing the high-speed paper machine of high productivity the drying performance was reevaluated. And the machine was improved by the procedures such as the adoption of forced exhaust, introduction of hot blast supply equipment, complete sealing of hood and building-in of waste heat recycling device. In case of the totally sealed hood, it is possible to make a theoretical design and to calculate the heat balance easily. On the other hand, in case of the open-type hood, it is possible to sequentially modify and improve it to meet the production requirements in the actual operation.

The air volume normally required per 1 ton of paper is as follows:

Hoodless paper machine	75-80 tons
Paper machine with open-type hood	50-60 tons
Paper machine with closed-type hood	25-30 tons

If the hood device is improved, less air consumption is required, and subsequently, the unit steam consumption rate is reduced. Fig.2.4.3 shows the difference between the open-type hood and the closed-type hood. When the dryer is at a marginal capacity, an approx. 20% increase of the capacity is expected, if the closed-type hood is adoped.

b) Improving the dryer ventilation

In the case of the closed hood, it is recommended that the ventilation system be built into the paper machine with the dryer. Otherwise, the drying effect would be reduced. The well-balanced air supply and exhaust, and appropriaate temperature are contributing factors toward the effective consumption of thermal and electric energies and the stabilization of paper quality.

Water vaporized from the dryer part is released as an exhaust of high dew point. It is suggested that air or water at high temperature be obtained by heat exchange in the process of this release, and that hot air be used as an air supply to the dryer and hot water as blanket washing and pulp washing process.

The dryer ventilation system is a system where high-efficiency vaporization and waste heat recycling are carried out by means of ventilation control. One example of this system is shown in Fig.2.4.4. The waste heat recycling flow and the ventilation control system are shown Fig.2.4.5.

The pocket ventilation system is effective for equalizing moisture distribution across the entire width of wet paper and thus economizing steam consumption. In addition, this system prevents overdrying at both ends of the paper annd also prevents paper break. Therefore, its effects are remarkable. In case of open hood, the stagnation of vapor is a problem remaining to be solved. The devices such as PV roll and Grevin nozzle incorporated in the canvas roll are also available. In some cases, air is injected into a part where vapor is stagnant.

3. Energy Conservation through Waste Heat Recovery

There are many energy conservation measures in major energy consuming industries. Among them, "recovery and utilization of waste heat" is the most fundamental and important measures in energy conservaion technologies. Therefore, the subject of this technology will be mainly discussed below.

There are various sources of waste heat in a plant. Before the first oil crisis in 1973, fuel prices were so low that waste heat recovery equipment and operations costs exceeded savings achieved from recovered heat. Therefore, waste heat recovery devices were not installed. However, with the sharp rise in fuel prices during the first oil crisis, waste heat recovery devices now are being introduced more widely.

The following type of waste heat recovery are explained below:

a) Heat recovery from combustion exhaust gas

b) Recovery of steam condensate

c) Heat recovery from hot waste water

3-1 Heat Recovery from Combustion Exhaust Gas

Even if low air raio combustion and internal furnace pressure management are implemented well, thermal efficiency is very low for high temperature equipment such as heating furnace. The relation between air ratio and exhaust gas loss is illustrated in Fig.3.1 which indicates that when the exhaust gas temperature at the outlet port of a furnace is 1000 C, about 50% of the heat produced from fuel becomes exhaust gas heat loss even if the air ratio is lowered to 1.2. For that reason, it is necessary to recover the sensible heat of exhaust gas and effectively utilize the heat to increase the heating furnace's thermal efficiency. Fig.3.2 shows typical example of recovery and utilization of exhaust gas.

a) In example A and B, recovered heat is used by the furnace to preheat combustion air and raw materials.

b) In example B and E, recovered heat is used by other equipment to generate steam in a waste heat boiler and reutilized in a low temperature furnace.

c) In example C, several kinds of heat recovery are combined so that heat recovered by a turbine is converted into electric power, etc.

Waste heat recovery should be considered after all energy conservation measures have been taken. Minimizing the generation of waste heat is the most important objective.

(1) Preheating of Raw Materials

When raw materials are preheated by exhaust gases before being placed in a heating furnace, the amount of fuel necessary to heat them in the furnace is reduced. Since raw materials are usually at room temperature, they can be heated sufficiently without using high-temperature gas.

(2) Preheating of Combustion Air

For a long time, preheating of combustion air using the sensible heat of exhaust gas has not been used except for large boilers, metal heating furnaces and high-temperature kilns. This method is now being employed in compact boilers and compact industrial furnaces as well.

Table 3.1 shows the outlines of air preheaters. In addition, heat pipe type heat exchangers and high temperature gas/gas plate heat exchangers can serve as air preheaters.

When combustion air is preheated, a quantity of fuel equal to the sensible heat brought in by the preheated combustion air is conserved. The fuel conservation rate S due to the preheating of the combustion air is determined according to the formula below (refer to Fig.3.3).

$$S = \frac{P}{H_l - Q + P}$$

P : Quantity of heat brought in by preheated air kcal/kg-fuel

Q : Quantity of heat taken away by combustion gas kcal/kg-fuel

H_1 : Heating value of fuel kcal/kg

The results of calculations of consevation of fuels according to the formula above are shown in Fig.3.4.

For example, when combustion air for heavy oil is preheated to 400 C by a heat exchanger with an inlet temperature of 800 C, Fig.3.4 suggests a fuel conservation rate of about 20%.

Since the volume of air is increased due to its preheating, it is necessary to be careful about the modification of air duct diameters and blowers. As for the use of combustion gases resulting from high-density oils with high sulfur contents, care must be paid to avoid problem such as clogging with dust or sulfides, corrosion or increases in nitrogen oxides.

(3) Utilizing Waste Heat as a Heat Source for Other Processes

The temperature of heating furnace exhaust gas can be as high as 400 to 600C, even after heat is recovered from it.

When a large amount of steam or hot water is needed in a plant, installing a waste heat boiler to produce the steam or hot water using the exhaust gas sensible heat is preferred.

If the exhaust gas sensible heat is suitable for equipment in terms of heat quantity, temperature range, operating time, etc., fuel use can be much curtailed. In one case, exhaust gas from a quenching furnace was utilized as a heat source for a tempering furnace so as to make it completely unnecessary to use fuel for the tempering furnace itself.

3-2 Recovery of Steam Condensate

Although steam is used most as an energy sources, the rate of actual effective utilization of steam's total heat energy is about 80%. Therefore, fuel savings of about 20% can be achieved by recovering 100% of the heat of the condensate and effectively utilizing the recovered heat.

The recovered condensate generally is utilized for boiler feed water. The effects of the recovery of the condensate are mentioned below.

a) The consumption of boiler fuel is dimished, thereby reducing air pollution. When the recovered condensate is used as boiler feed water, its temperature is raised. If the feed water temperature is raised by 10C, fuel consumption can be reduced by about 1.5% (as understood from the relation between the feed water temperature and fuel conservation shown in Fig.3.5).

b) Recovered condensate can be reused as boiler feed water to reduce the total amount of boiler feed water. Since the recovered condensate is pure water, the cost of water purification is reduced.

(1) Planning of Condensate Recovery

In planning the recovery of condensate, the two factors noted below are generally examined:

a) Effects of condensate recovery processes on cost reductions and management of operations.

b) Cost of installing condensate recovery equipment.

These two factors are compared to estimate whether or not condensate recovery is cost effective and to determine the optimal recovery method if it is utilized. For these purposes, and to clarify which condensate should be recovered, it is necessary to find out how much steam in plant is now used in each of its processes and how much condensate is abondoned.

Therefore, heat balancce sheets should be drawn up to help in grasping the overall heat use situation. Ey trial calculation of equipment costs, a condensate ecovery method needs to be selected..

(2) Methods for Recovering Condensate

There are three methods of recovering a high-temperature condensate drained through a steam trap, as follows:

a) Recovering condensate only by using steam trap

b) Recovering condensate using steam trap and volute pump.

c) Recovering condensate using steam trap and condensate recovery pump.

In method a and b, a condensate recovery line is open to the atmosphere, and the temperature of the recovered condensate cannot be made higher than 100C. In method c, the condensate recovery line is closed to the atmosphere, and all the heat of the drained condensate can be recovered. Method c has been widely used in recent years.

Fig.3.6-3.8 show the condensate recovery methods.

(3) Utilization of Flashed Steam

When a pressurized condensate with a temperature of 100C or more is released into the atmosphere, a part of the condensate is flashed into steam. Though the pressure of the flashed steam is low, there is a process by which it can be utilized effectively.

Table 3.2 shows the quantity of flashed steam. It is understood from this table that flashed steam of 2 kg/cm^2 is generated in a quantity of 1 t/h from 10 t/h of condensate of 10 kg/cm^2.

Fig.3.9 shows an example of utilization of flashed steam. The places where condensate is generated and flashed steam is used should be near each other so that the already low pressure of the flashed steam is not reduced further through unnecessarily long piping transport. For that reason, large diameter piping must be used and equipment costs are high. Therefore, thorough study of the cost effectiveness of using flashed steam should be carried out before deciding on its use.

(4) Items to Keep in Mind Concerning Condensate Recovery

Items which should be kept in mind about condensate recovery are noted below. Together with the maker of steam condensate recovery equipment, on-site technical study of these items is necessary.

a) Though the recovered condensate tends to be considered pure distiled water, the condensate contains minute quantities of various substances dissolved in it. It should be studied to see if the condensate can be used as boiler feed water as is.

b) If the condensate cannot be used as is, studies should be carried out to determine how to treat the condensate and whether or not to recover only heat if the condensate is very contaminated.

c) Since the steam trap receives back pressure from a condensate recovery pipe or equipment, the trap should be changed for a mechanical trap. Careful appraisal is necessary in selecting the appropriate mechanical trap.

d) If there are piping lines with different steam pressures, study will be necessary to determine if condensate recovery pipes should be provided for the different levels of steam pressure.

3-3 Heat Recovery from Hot Waste Water

Hot waste water is a form of waste heat apt to be overlooked. Though it is not readily utilized, a method of utilizing the heat should be developed if a large amount of heat is being lost.

Methods of utilizing the heat of hot waste water are mentioned below:

a) Recycling the hot waste water

b) Heat recovery using heat exchanger

c) Heating of feed water using heat pump

Typical method of recycling hot waste water involves utilizing again the water which performs indirect cooling in a condenser. The hot water is relatively clean so that it can be used for room heating or for bathing.

Though a heat exchanger was not used previously to recover heat because the heat exchanger soon became clogged due to unclean hot waste water, a plate-type heat exchanger which is cheap and from which scale can be completely removed has been developed and used in dyeing plant and in a boiler to exchange heat between hot waste water and clean water in order to heat the clean water which then is used. This method has yielded good results.

Though a heat pump was developed for use in air-conditioning, it also has been used recently to recover the heat of hot waste water. Hot waste water of 30 to 40 C is used as a heat source in a heat pump to heat feed water to 70 to 80 C and energy savings about 50% greater than those realized with heat recovery using only a conventional heat exchanger were achieved. Fig.3.10 shows basic flows in the use of a heat pump.

4. Conclusion

As stated thus far, energy conservation in Japan, which had been progressing remarkably in each field, has, for the past several years, been in a state of stagnation owing to low and stable energy prices, including oil, and the spread of energy conservation technology. Energy consumption has been showing substantial increases since 1987 due to the recovery of business based on economic policies to expand domestic demand, together with the sluggishness of investments in energy conservation in industry, the levelling off of improvement to the efficiency of energy consuming appliances, and the lowering awareness of the need for energy conservation. However, in the midst of increasing discussions regarding the global environment, especially the greenhouse effect caused by the emission of CO_2 accompanying energy consumption, and forecasts of a tightening in medium- and long-term energy supply and demand, there are strong demands throughout the world to adopt new measures to take energy conservation one step further. It is important to push ahead with strong measures from a new standpoint in the fields, where adequate measures have, to date, not necessarily been adopted, as well as to continue the steady promotion of existing measures.

For example, Japanese industry has been collecting and using to great extent the waste energy that can be used within the factories economically (including gas produced as a by-product of the manufacturing process). However, apart from joint use by sections of an industrial complex, the use of waste energy outside the factory that actually produces it is rarely seen owing to such problems as the system, technology and economic viability. In the West, waste heat generated by power stations is used in heat supply projects, whereas in Japan this does not occur because of the differences in generating systems, and because there is not a stable demand for domestic-use heat. Furthermore, in urban areas a variety of heat sources, such as heat generated by rubbish incineration plants, subways, and the sewage treatment process, were, in the past, wasted, however these heat sources are now starting to be used, and the future use of waste energy within the social structure has become a major topic.

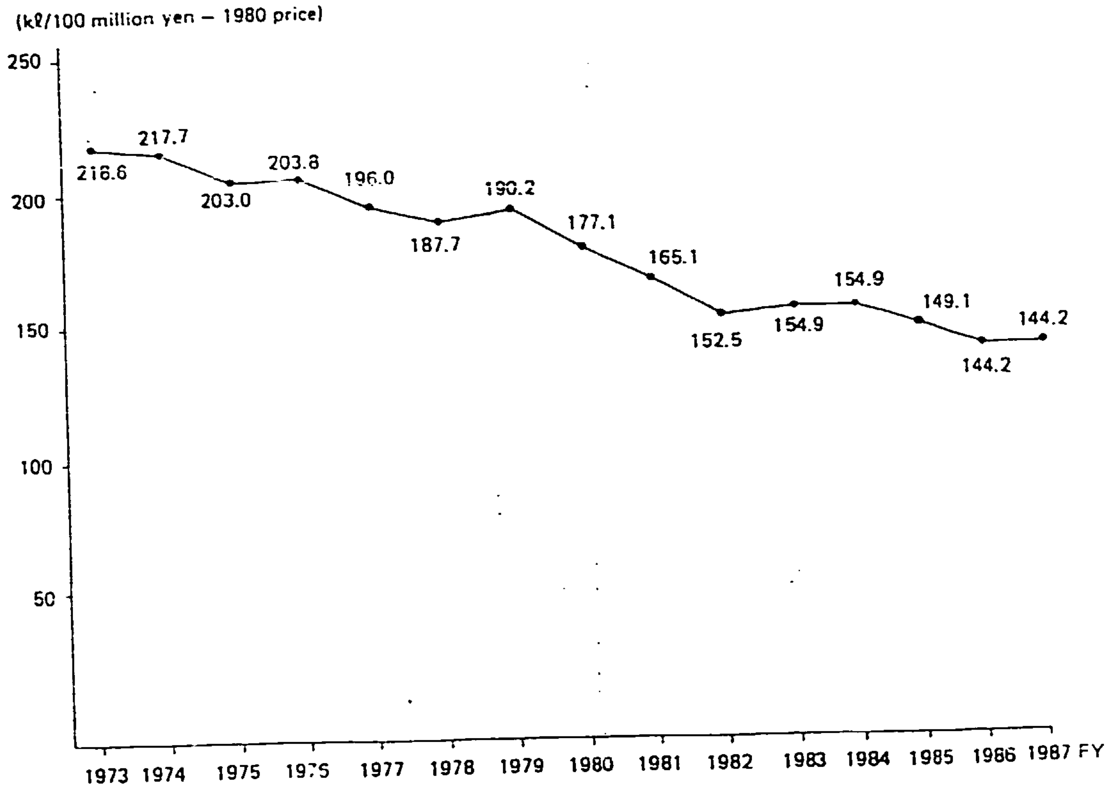


Fig.1.1 Changes in the TPER/GNP Ratio

Table 1.1 Change in Energy Consumption

Fical year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Index	100	99.6	92.9	93.2	89.7	85.9	87.0	81.0	75.5	69.8	70.9	70.9	68.2	66.0	66.0

*Indices (FY 1973 = 100)

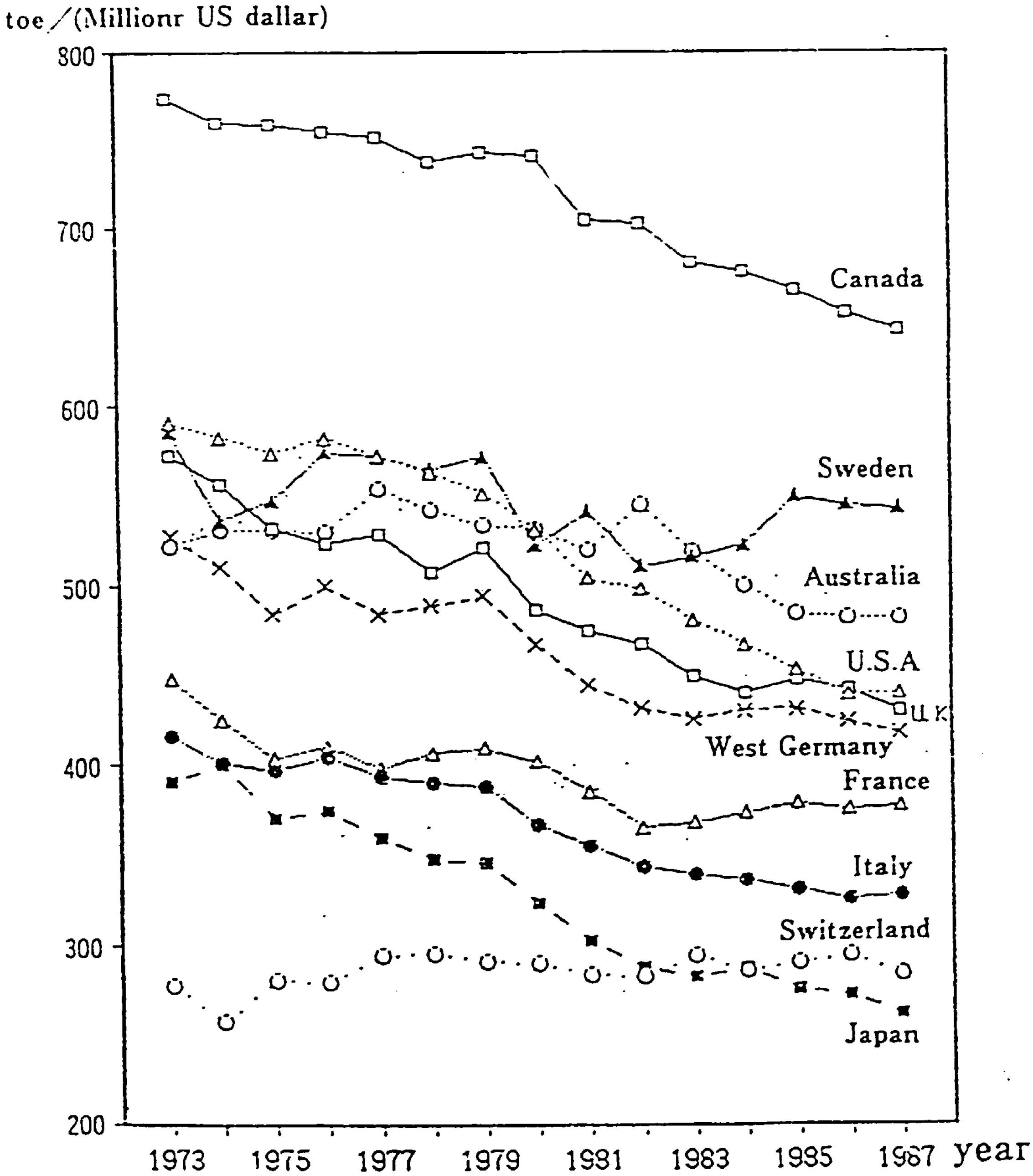


Fig.1.2 Trend of Total Primary Energy Requirement/GDP of OECD Countries

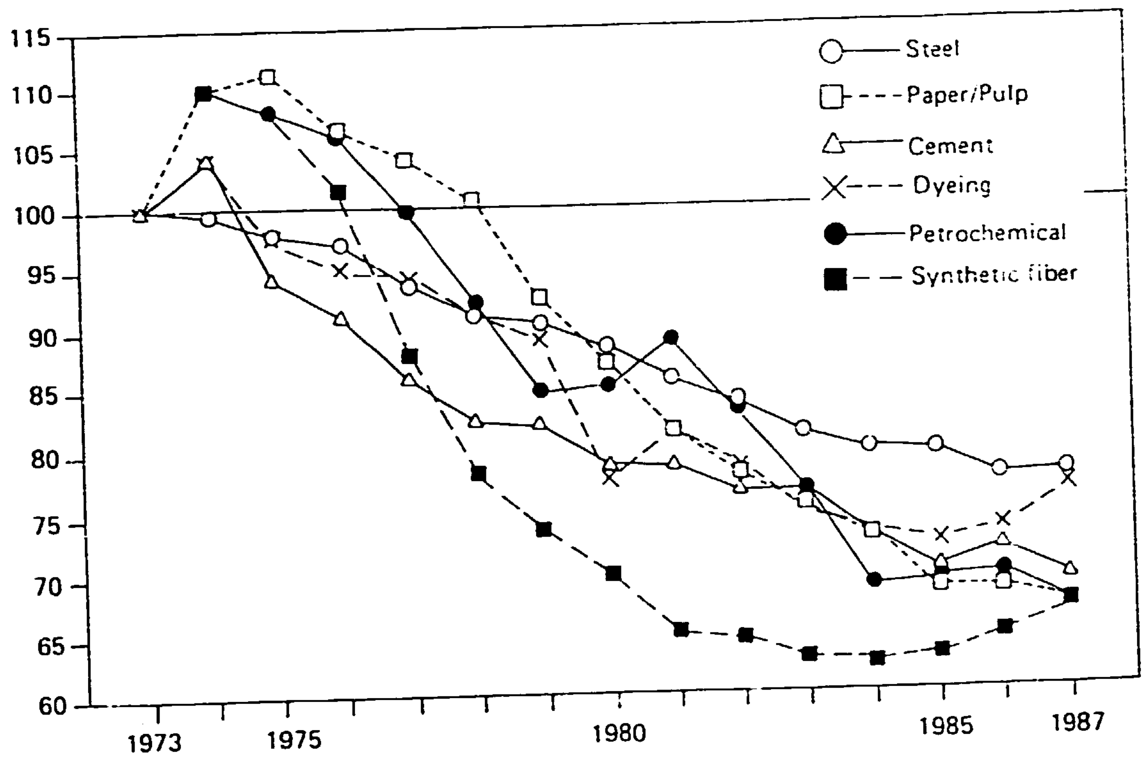
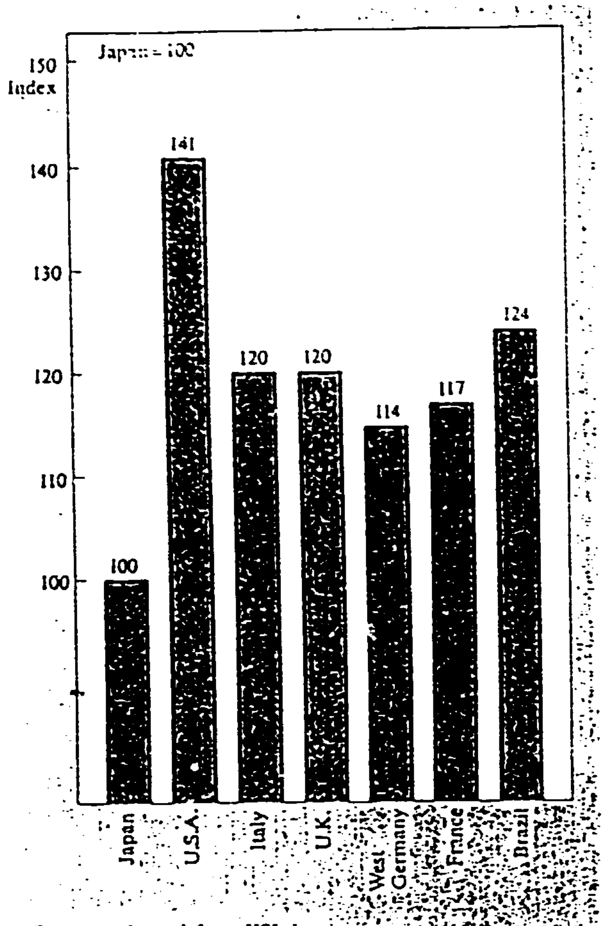
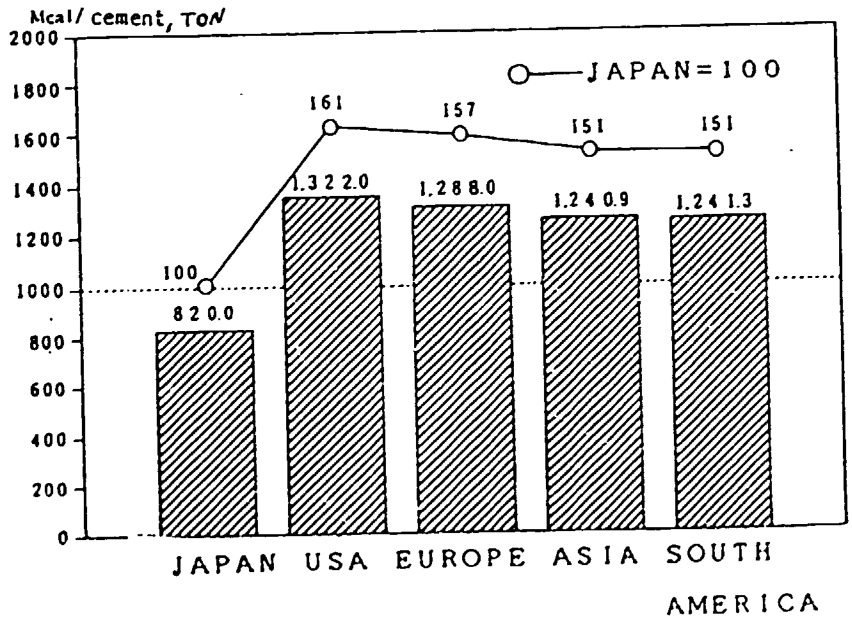


Fig.1.3 Unit Consumption of Energy in Major Industries
(1973 value: 100%)



Source: estimated from IISI data.

Fig.1.4 Real Sspecific Energy Consumption in Major Steelmaking Countries, 1987



CEMBUREAU ; WORLD CEMENT DIRECTORY

Fig.1.5 Real Specific Energy Consumption in Cement Industry

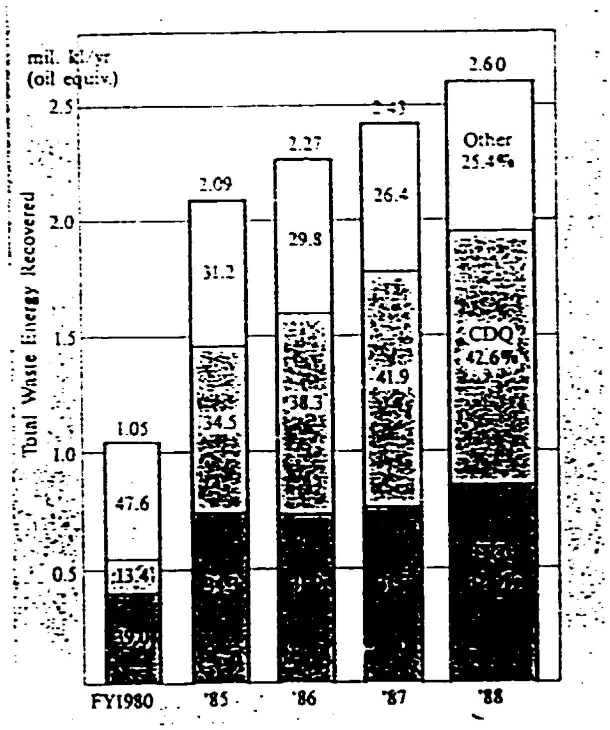


Fig.2.1.1 Recovery of Waste Energy Generated by Integrated Steelworks

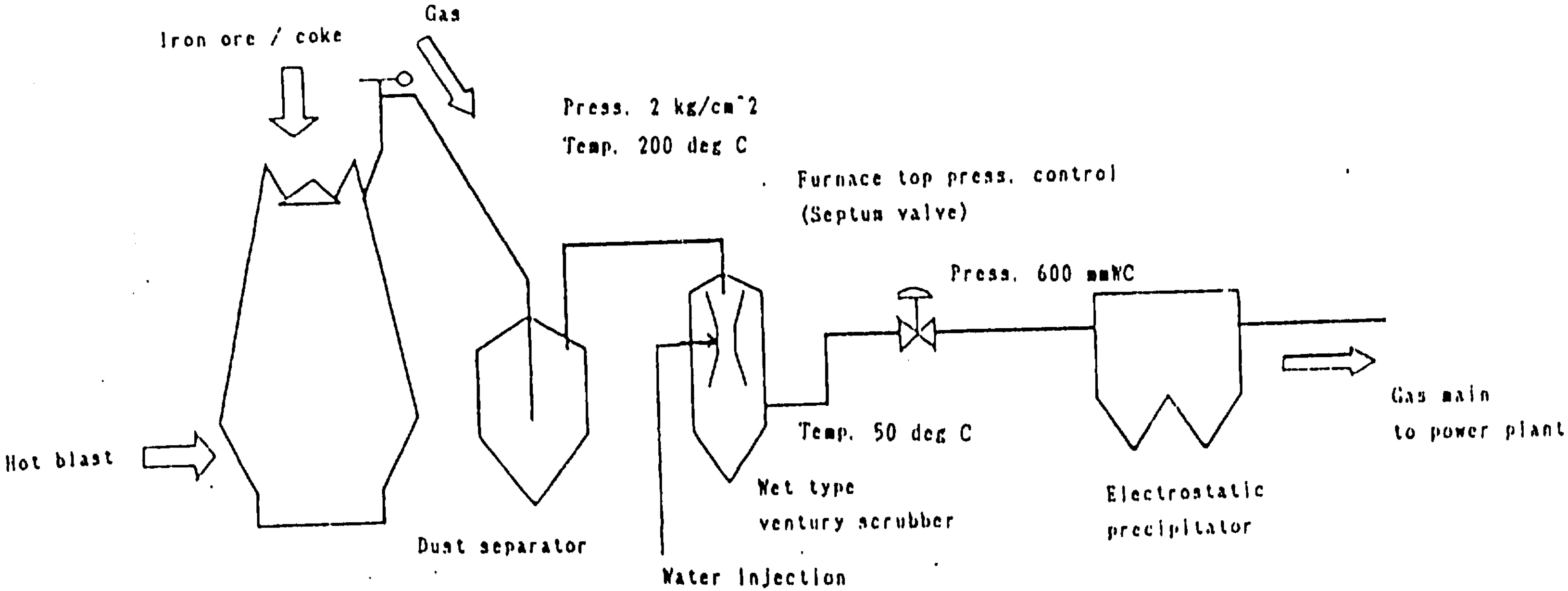


Fig.2.1.2 Blast Furnace Gas Flow
(conventional)

5

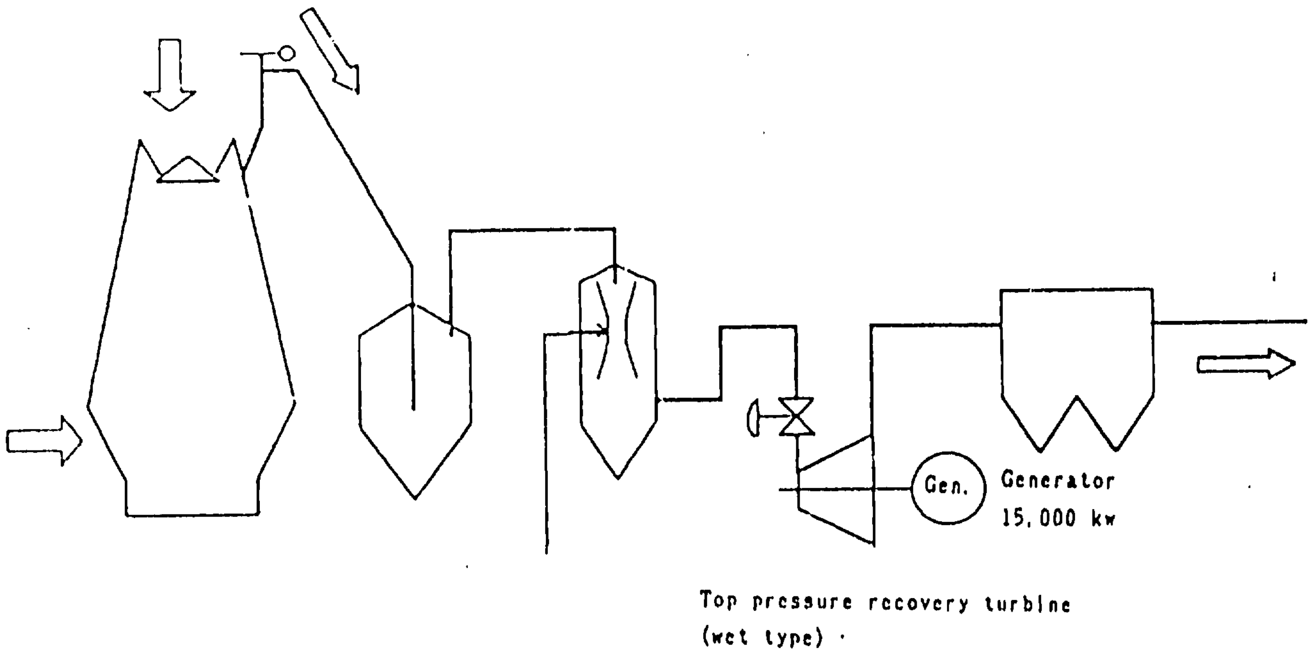


Fig.2.1.3 Blast Furnace Gas Flow
(wet type top pressure recovery turbine)

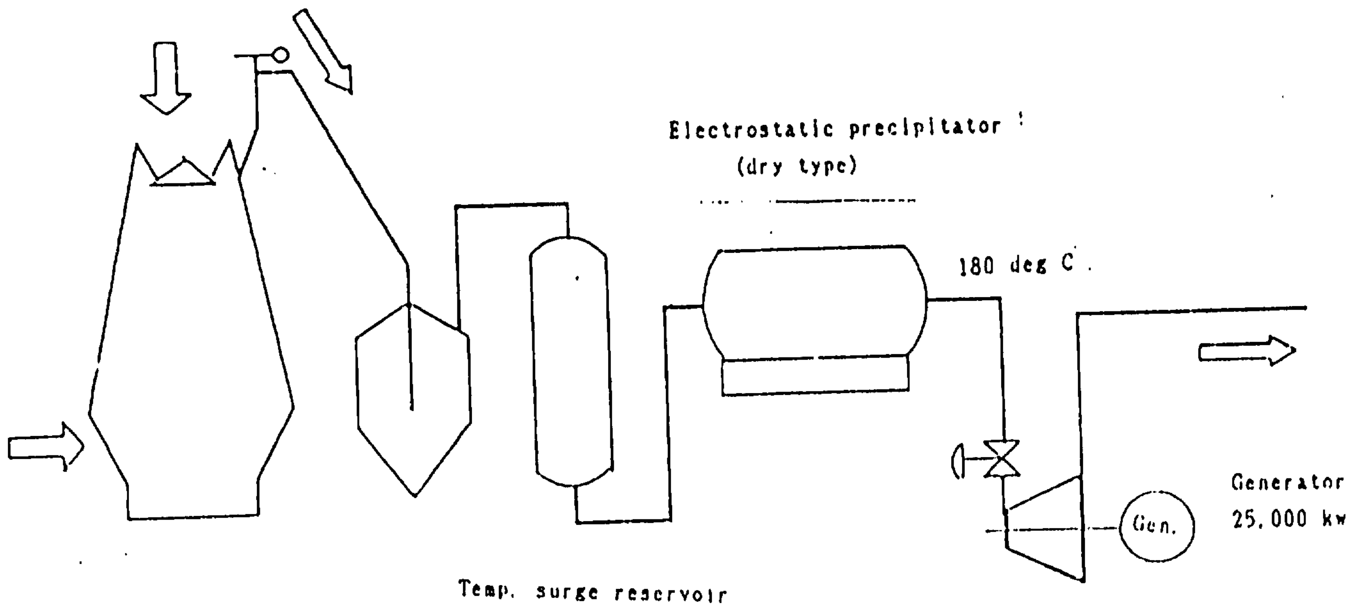


Fig.2.1.4 Blast Furnace Gas Flow
(dry type top pressure recovery turbine)

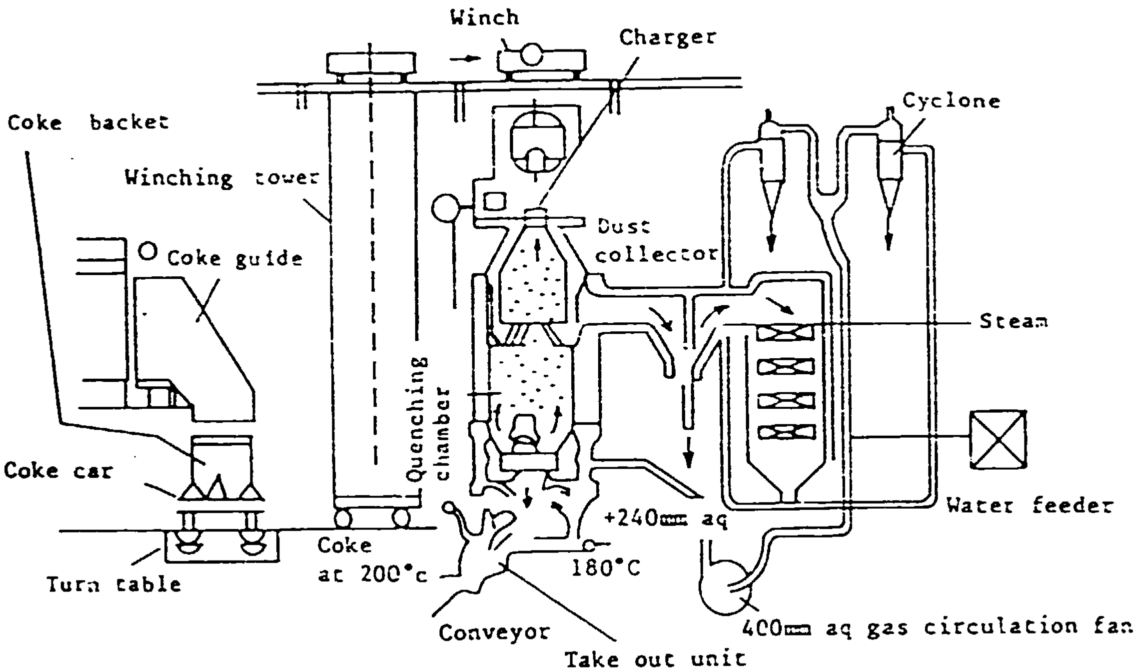


Fig.2.1.5 Coke Dry Quenching Equipment

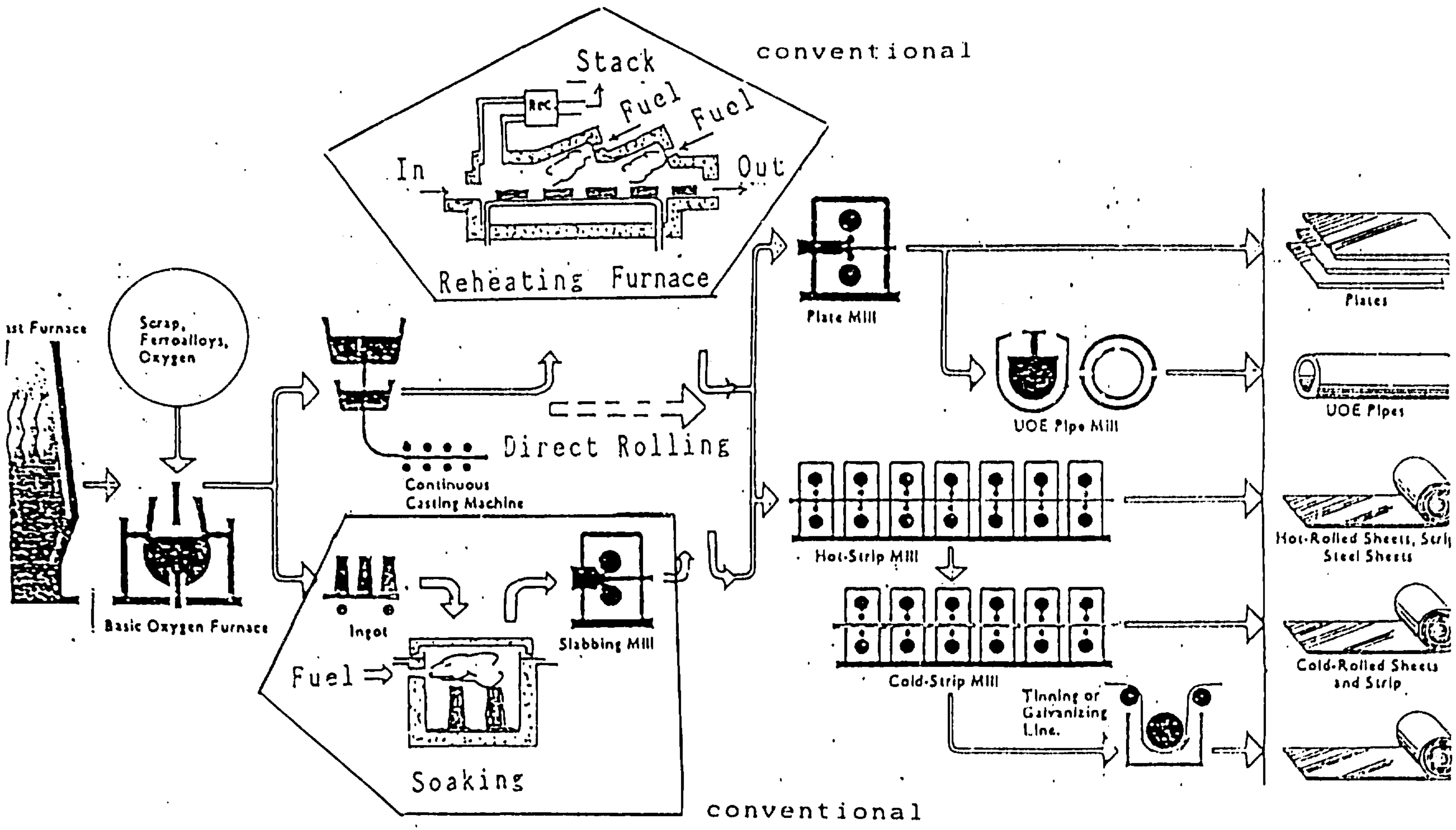


Fig.2.1.6 Steel Products Manufacturing Process (conventional/energy saving)

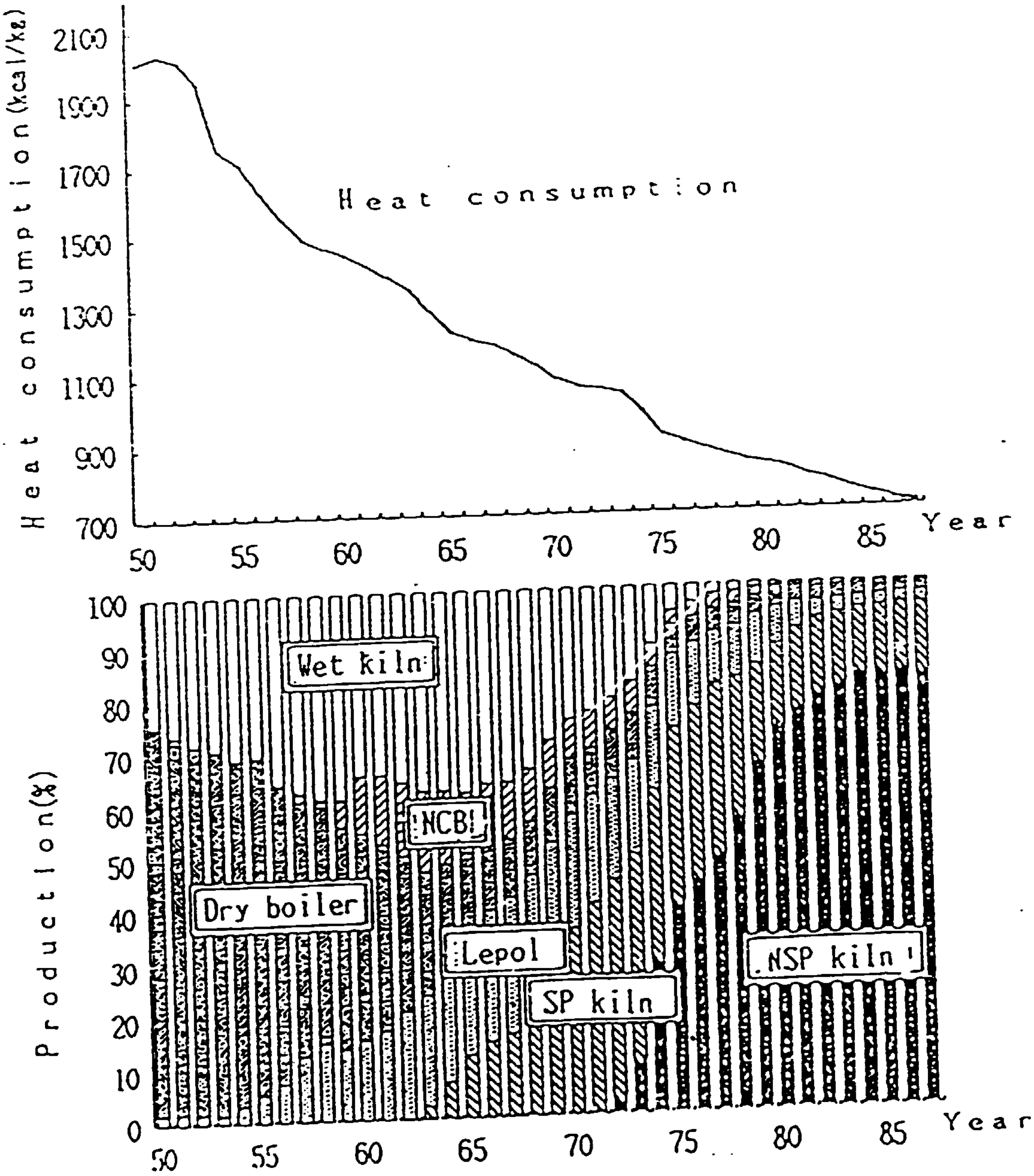


Fig.2.2.1 Heat Consumption and Production Classified by the Type of Kiln

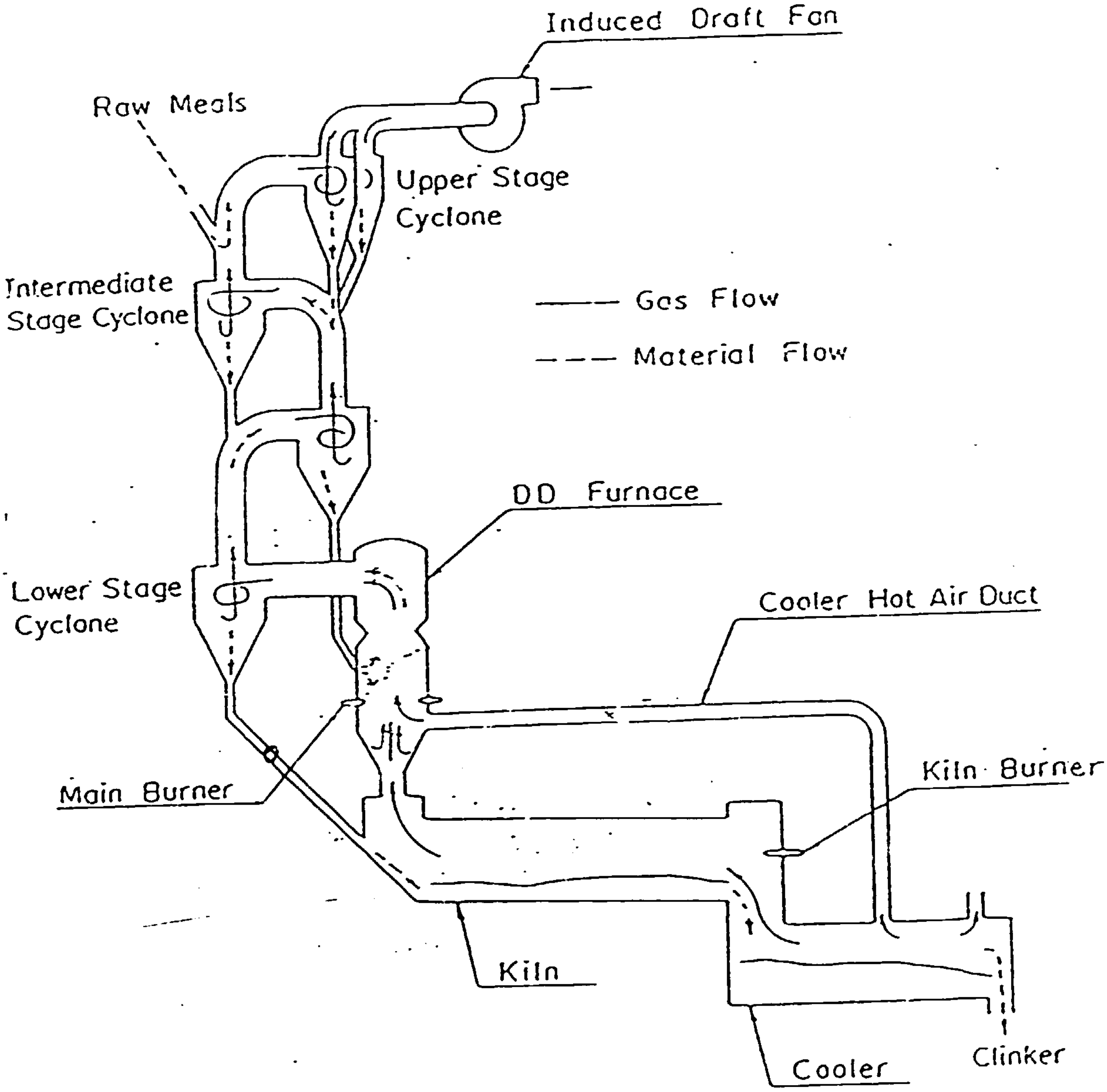


Fig.2.2.2 Gas and Material Flow in NSP Kiln

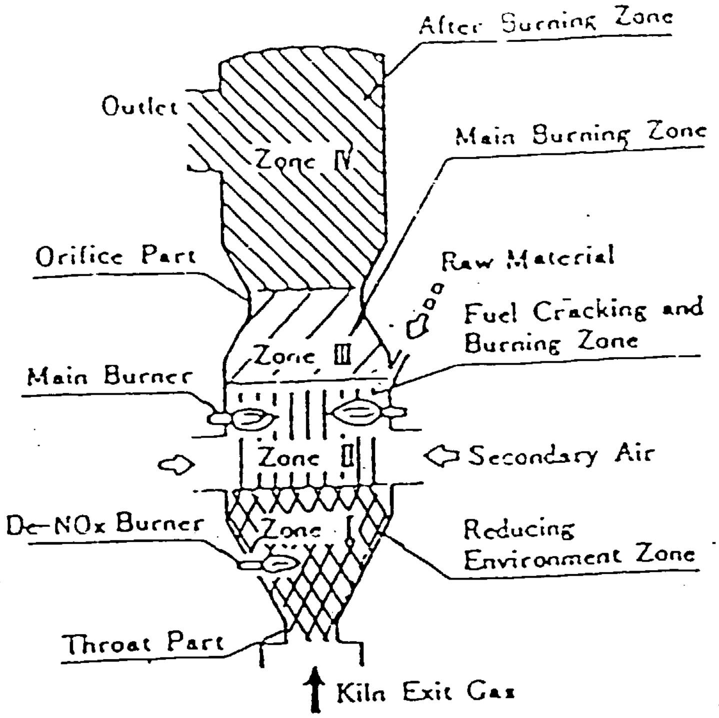


Fig.2.2.3 Zone and it's Function in DD Furnace

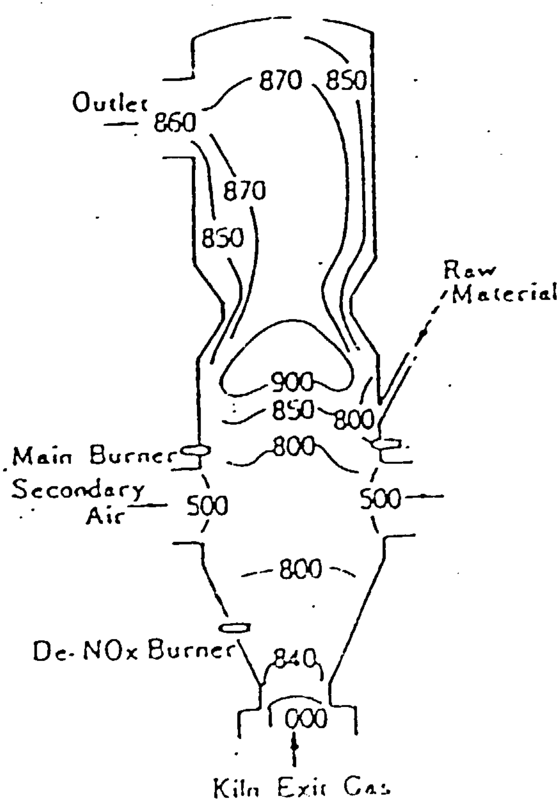


Fig.2.2.4 Temperature Pattern in DD Furnace

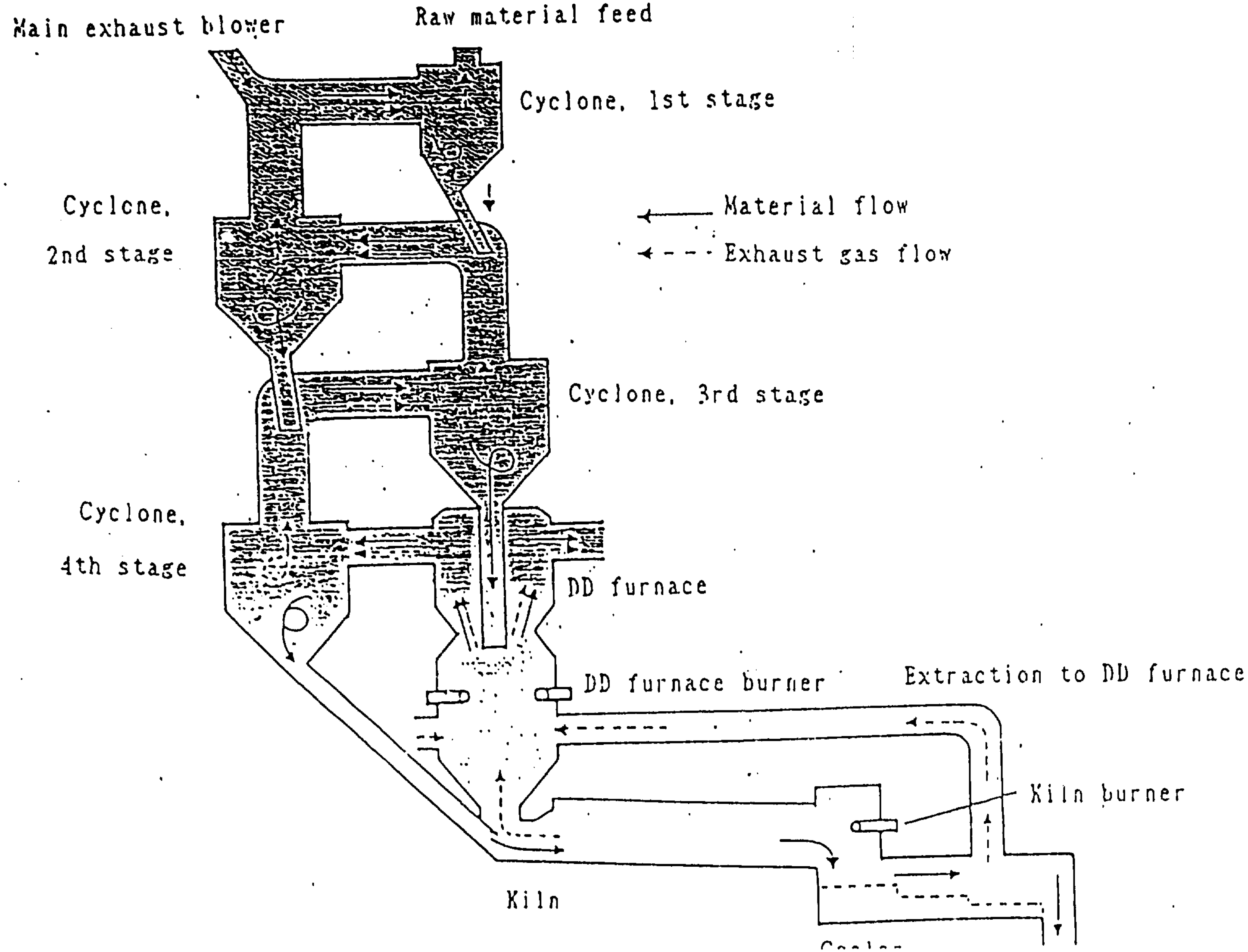


Fig.2.2.5 Suspension Preheater

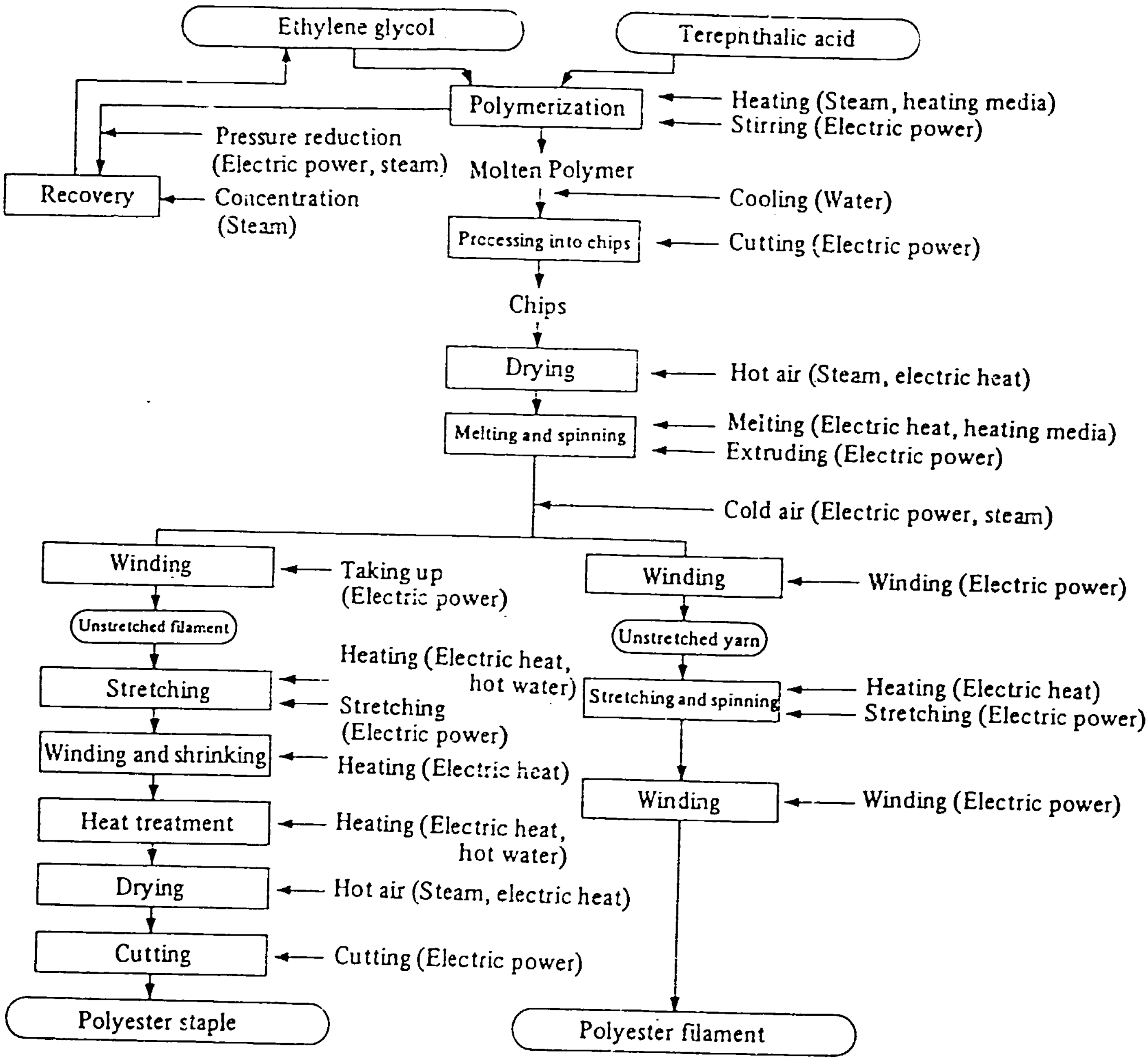


Fig.2.3.1 Polyester Production Process

Table 2.3.1 Production vs. Energy Consumption in Synthetic Textile Industry

Year	Production (thousands of tons/year)	Fuel oil consumption (liters/kg)	Electric power consumption
1971	1662.3	1.42	2.82
1973	1847.8	1.36	2.76
1975	1452.3	1.49	3.17
1977	1734.9	1.22	2.70
1979	1850.7	1.00	2.43
1981	1815.8	0.78	21.7
1983	1786.1	0.67	2.15
1985	1861.1	0.45	2.11
1986	1760.1	04.1	2.18
1987	1727.6	0.38	2.22
1988	1735.3	0.36	2.24

Source: MITI statistics "Textile Statistics Annual Report"

Table 2.3.2 Main Energy Conservation Measures in Synthetic Fiber Factories

Energy saving measure	Equipment
Recovery and reuse of waste heat	
• Use of waste heat	Waste heat boiler
• Multi-effect use of evaporator	Adding/improving evaporator
• Use of low-temperature waste heat	Heat pump
• Power generation using low/ medium-temperature waste heat	Low-voltage generator, etc.
Effective use of energy	
• Heat storage using nighttime electricity	Accumulater
• Raising efficiency of electrical equipment	High-efficiency electrical eqipment
Rationalizing operation	
• Integrated operation of equipment	Automatic controller
• Intermittent operation of pumps and ejectors	
Optimizing equipment capacity	
• Equipment speed (rpm) control	Speed controller
Combustion control	Automatic controller
Process improvement	Continuous polymerization spinning equipment Drawing, false twisting machine, etc. High-speed multi yarn reeling machine, etc.

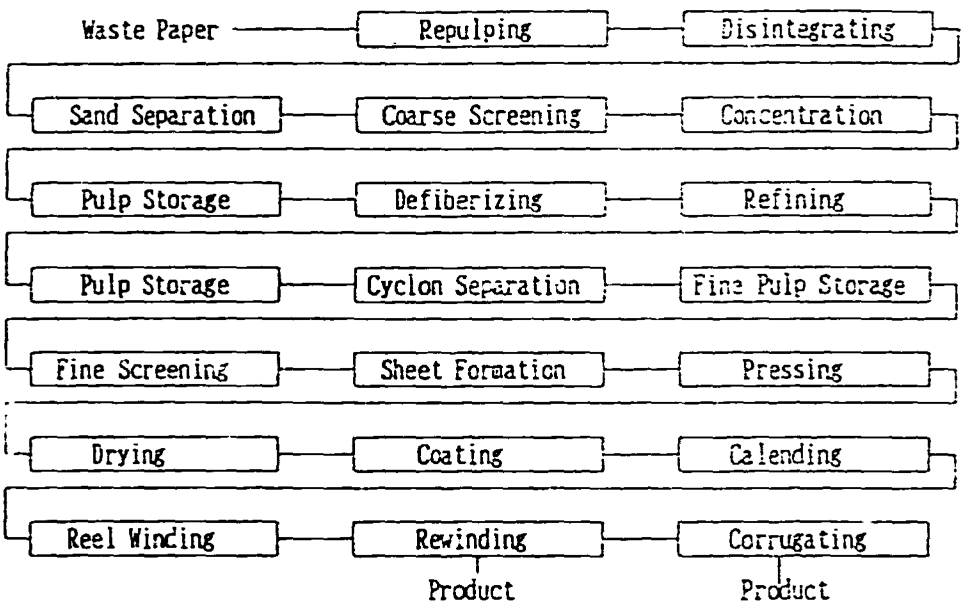


Fig.2.4.1 Paper Production Process

Table 2.4.1 Equipment and Energy of Paper Mill

Name of equipment	Purpose	Energy source
Pulper	Pulp disintegration	Electricity and steam
screen separator	Removal of undissolved and foreign matter	Electricity
Filter Thickner	Pulp washing and concentrate	Electricity
Beater Refiner	Fiber beating and defiberizing	Electricity
Chest	Circulation of stored pulp	Electricity
Cyclone separator	Separation of united fiber and microparticles	Electricity
Paper machine	Driving of wire part, press part and dryer part	Electricity
Suction box Suction couch	Dehydration of wire part	Electricity
Suction press Suction box	Dehydration of press part	Electricity
Dryer	Drying of wet paper and canvas	Steam
Coater	Painting and drying	Electricity and steam
Calender	Smoothing and glossing	Electricity
Cutter	Cutting	Electricity

Table 2.4.2 Standard Unit Energy Consumption Rate of the Sheet Making Section in Japan

	Steam (t/t) 1979 Oct. ~ 1980 Sep.		Electricity (kWh/t) 1979 Oct. ~ 1980 Sep.	
	Range	Typical value	Range	Typical value
Printing paper A (high quality)	1.6 ~ 5.0	(3.2)	320 ~ 1,280	(775)
Printing paper B (intermediate quality)	1.9 ~ 3.6	(2.75)	480 ~ 940	(710)
Printing paper C (high groundwood paper)	1.9 ~ 3.1	(2.45)	440 ~ 950	(665)
Other printing and writing paper	1.9 ~ 3.6	(2.8)	370 ~ 790	(565)
Kraft paper (multiple sack use)	1.8 ~ 3.8	(2.60)	490 ~ 1,080	(770)
Kraft paper	2.1 ~ 4.2	(3.00)	420 ~ 1,450	(855)
Other wrapping paper	1.8 ~ 3.8	(2.95)	200 ~ 1,210	(750)
Kraft liner for external fitting	1.4 ~ 4.1	(2.60)	350 ~ 750	(540)
Jute liner for external fitting	1.6 ~ 2.9	(2.15)	300 ~ 700	(490)
Pulp core	1.7 ~ 2.9	(2.20)	30 ~ 600	(295)
Coated Manila cardboard	1.9 ~ 3.9	(2.90)	250 ~ 1,150	(700)
Coated white cardboard	1.8 ~ 3.4	(2.55)	220 ~ 650	(895)
Non-coated white cardboard	2.4 ~ 2.7	(2.55)	390 ~ 440	(420)
Core paper or Tube board	1.9 ~ 2.5	(2.20)	180 ~ 700	(430)
Color paper board	2.0 ~ 2.2	(2.05)	520 ~ 530	(525)

By courtesy of Japan Technical Association of Pulp and Paper Industry magazine No. 37-1 dated January, 1983

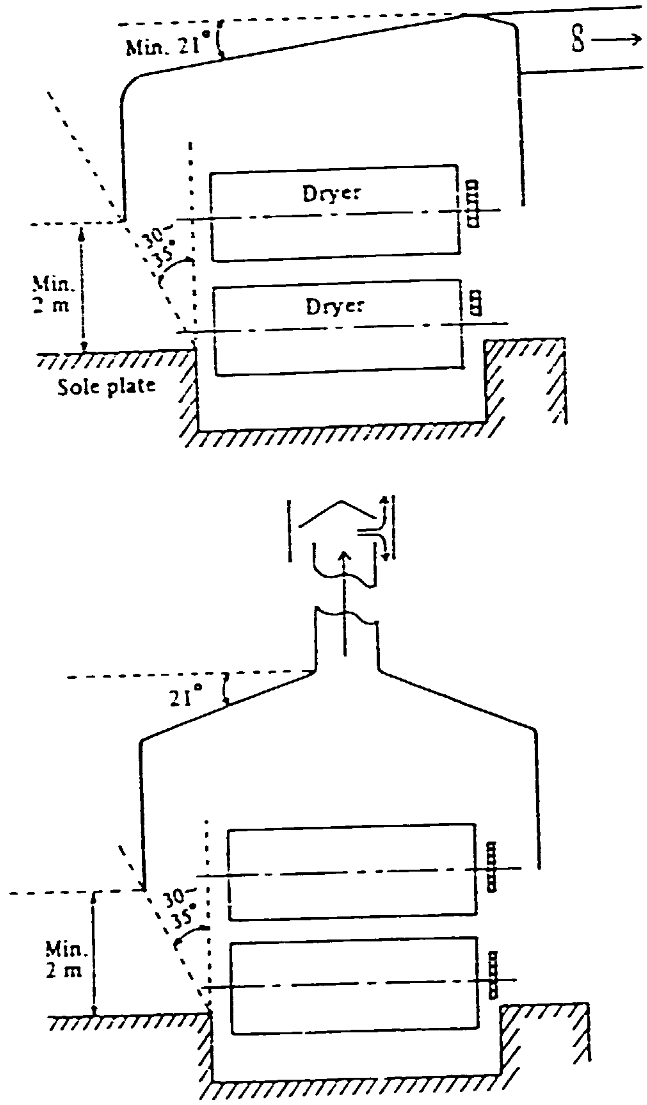


Fig.2.4.2 Structure of Open Hood

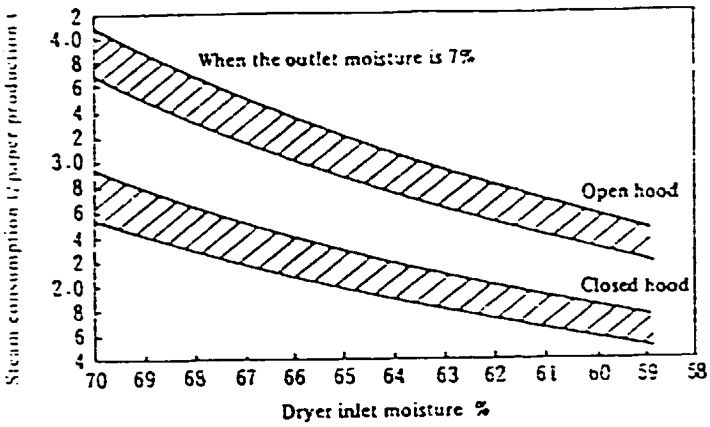


Fig.2.4.3 Unit Steam Consumption Rate for Open Hood and Closed Hood

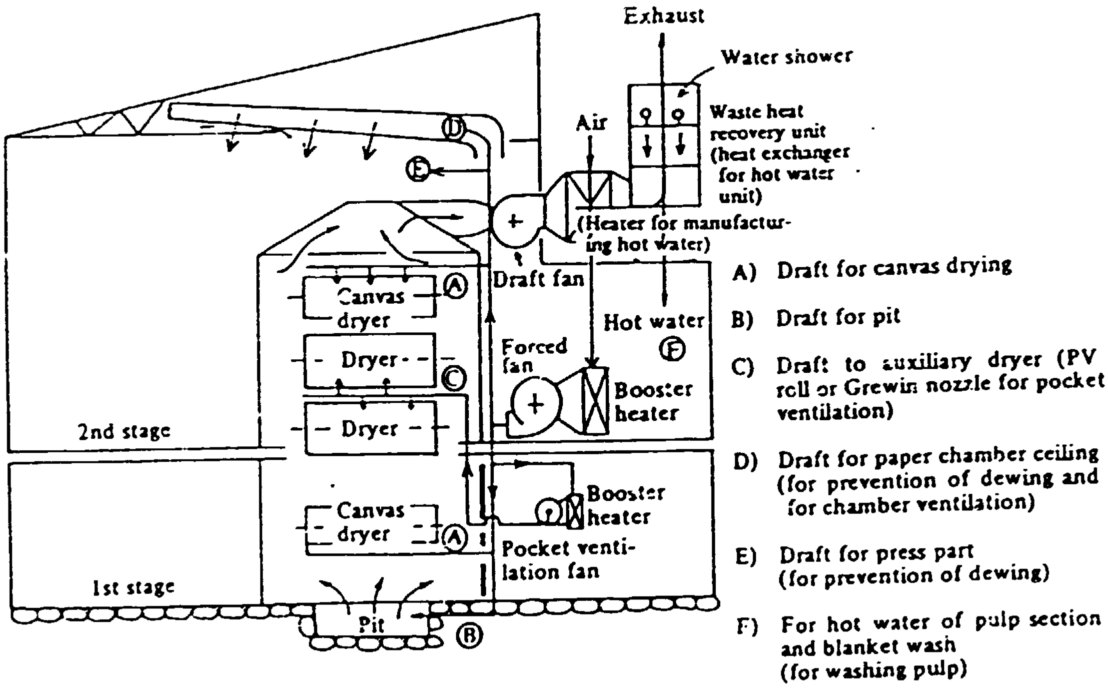


Fig.2.4.4 Example of Closed Hood Ventilation System

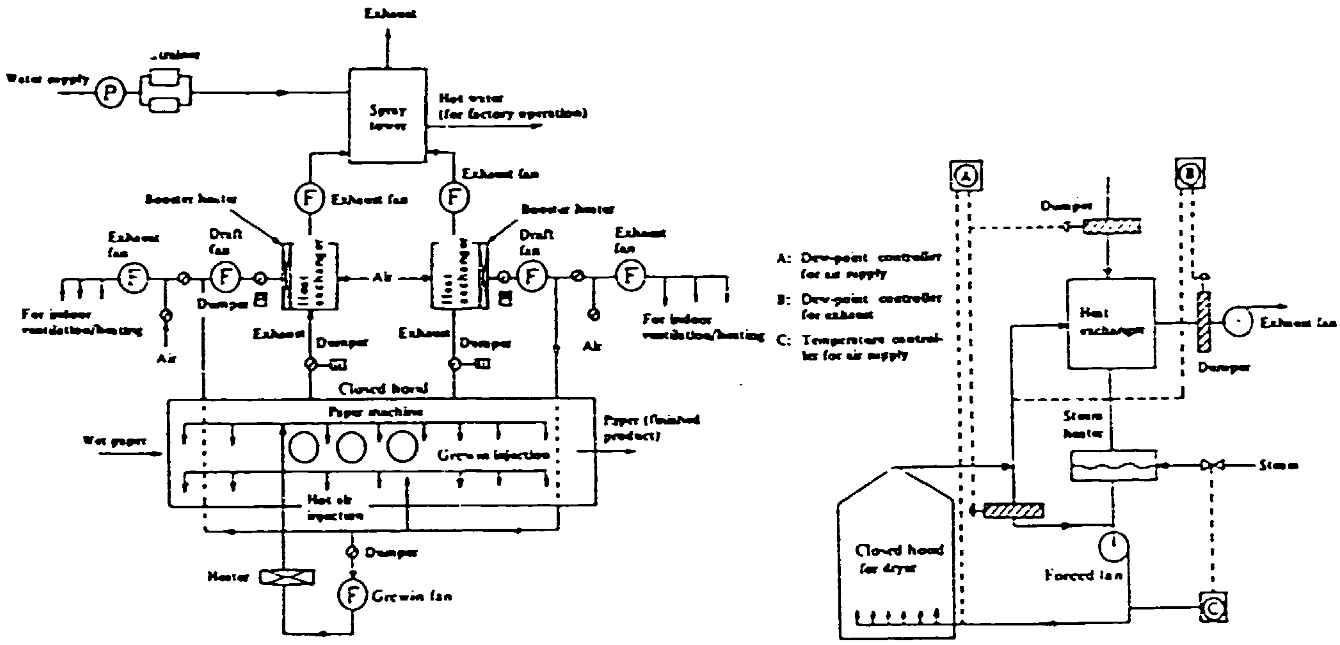


Fig.2.4.5 Waste Heat Recovery Low for Closed Hood Vetilation System and Control System

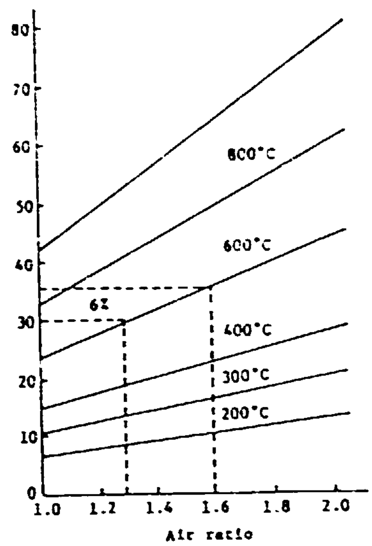


Fig.3.1 Relation between Air Ratio and Exhaust Gas

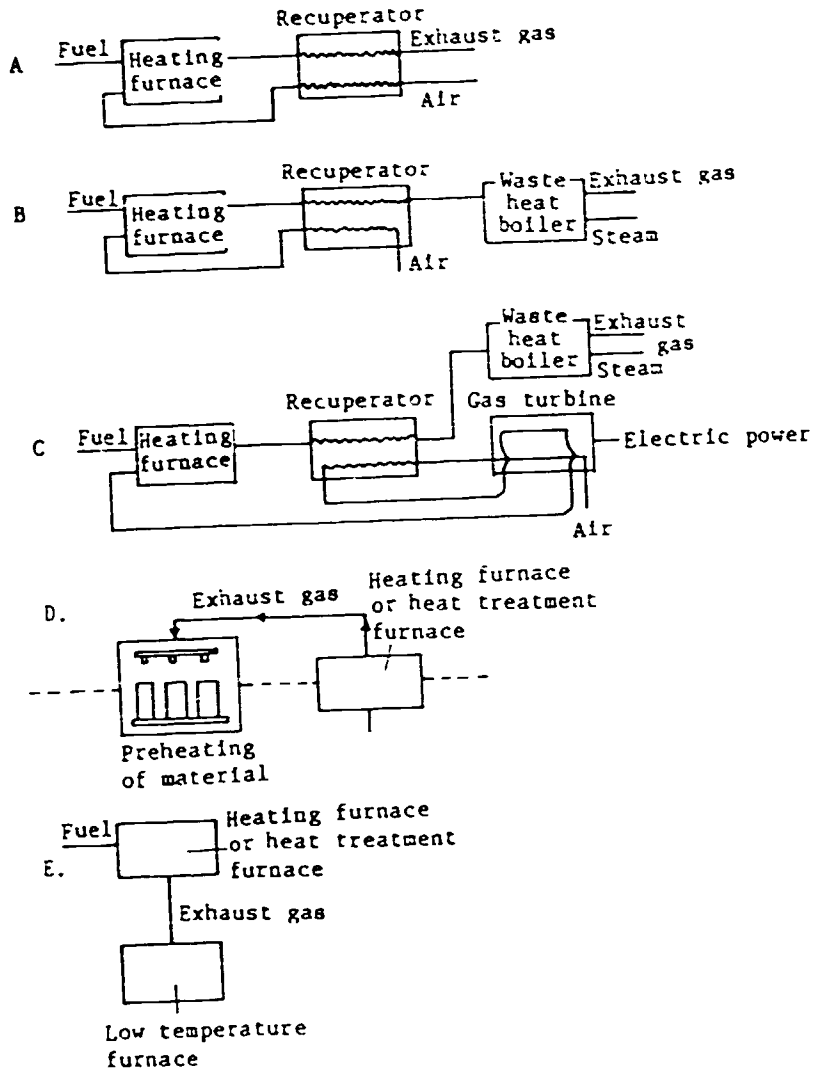


Fig.3.2 System for Utilizing Waste Heat of Combustion Furnace

Table 3.1 Outlines of Air Preheaters

Type				Exhaust gas temperature limitation	Preheated air temperature	Object furnace
Re-cuperative	Metallic recuperator	Flue installation	Convective: Multitubular Other	1,000°C or below	300 to 600°C	Heating furnace, heat treatment furnace and other industrial furnaces
		Chimney installation	Radiative (radiative and convective)	1,000 to 1,300°C		
	Ceramic (tile) recuperator		Armco Stein	1,200 to 1,400°C	400 to 700°C	Soaking pit & Glass kiln
Rege-nera-tive	General			1,000 to 1,600°C	600 to 1,300°C	Coke oven, hot blast stove & glass kiln
	Rotary regenerative (Ljungstroem; Rotemuihle)			600°C or below	100 to 300°C	Boiler, hot blast stove & anti-pollution equipment

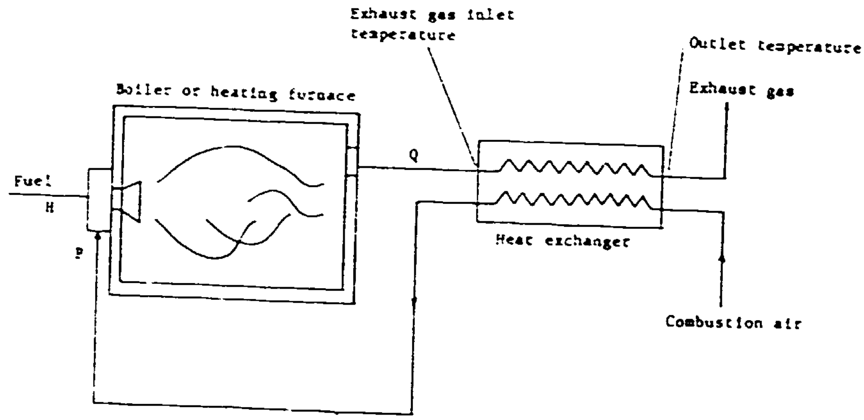


Fig.3.3 Example of Preheating of Combustion Air

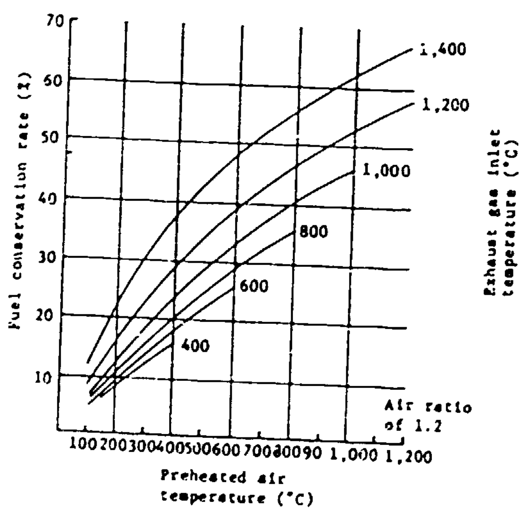


Fig.3.4 Conservation Rate for Heavy Oil

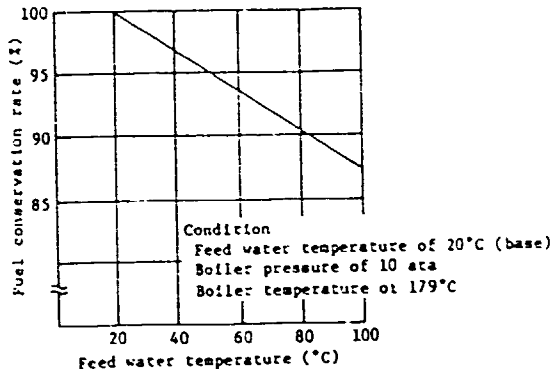


Fig.3.5 Feed Water Temperature and Fuel Conservation Ratio

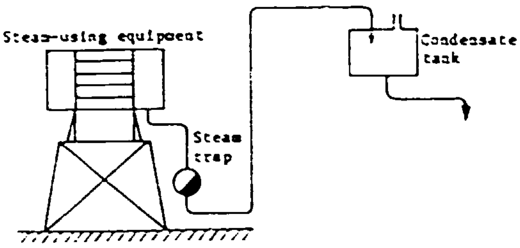


Fig.3.6 Condensate Recovery Only by Steam Trap

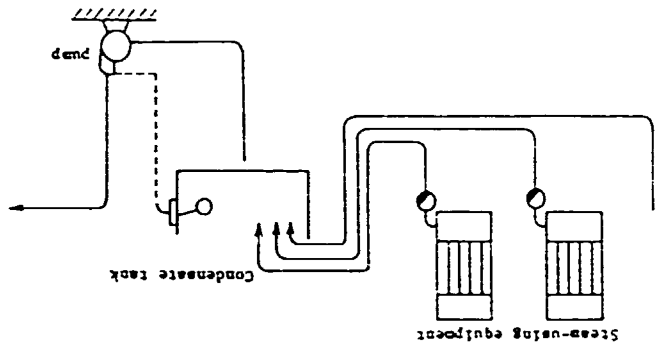


Fig.3.7 Condensate Recovery by Steam Trap and Volute Pump

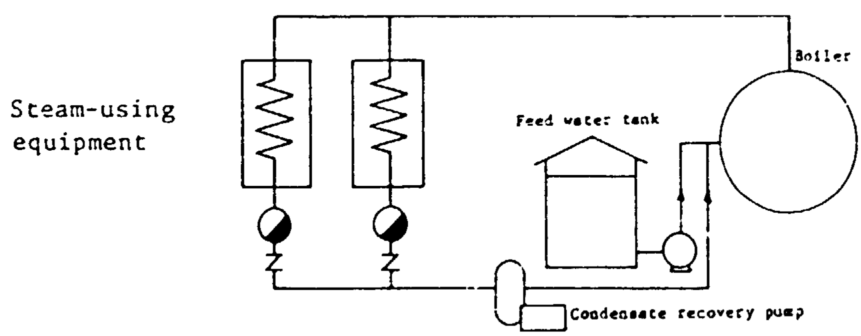


Fig.3.8 Condensate Recovery by Steam Trap and Condensate Recovery Pump

Table 3.2 Quantity of Flashed Steam (% by weight)

Higher pressure (kg/cm^2 g)	Lower pressure ($kg/cm^2 g$)															
	0	0.3	0.5	1	1.5	2	3	4	5	6	8	10	12	14	16	18
1	3.7	2.5	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-
2	6.2	5.0	4.2	2.6	1.2	-	-	-	-	-	-	-	-	-	-	-
3	8.1	6.9	6.1	4.5	3.2	2.0	-	-	-	-	-	-	-	-	-	-
4	9.7	8.5	7.7	6.1	4.8	3.6	1.6	-	-	-	-	-	-	-	-	-
5	11.0	9.8	9.1	7.5	6.2	5.0	3.1	1.4	-	-	-	-	-	-	-	-
6	12.2	11.0	10.3	8.7	7.4	6.2	4.3	3.0	1.3	-	-	-	-	-	-	-
8	14.2	13.1	12.3	10.8	9.5	8.3	6.4	4.8	3.4	2.2	-	-	-	-	-	-
10	15.9	14.8	14.2	12.5	11.2	10.1	8.2	6.6	5.3	4.0	1.9	-	-	-	-	-
12	17.4	16.3	15.5	14.0	12.7	11.6	9.8	8.2	6.9	5.7	3.5	1.7	-	-	-	-
14	18.7	17.6	16.9	15.4	14.1	13.0	11.2	9.6	8.3	7.1	5.0	3.2	1.5	-	-	-
16	19.0	18.8	18.1	16.6	15.3	14.3	12.4	10.9	9.6	8.4	6.3	4.5	2.9	1.4	-	-
18	21.0	19.9	19.2	17.7	16.5	15.4	13.6	12.1	10.8	9.6	7.5	5.7	4.1	2.7	1.3	-
20	22.0	20.9	20.2	18.8	17.5	16.5	14.7	13.2	11.9	10.7	8.7	6.9	8.3	3.8	2.5	1.2

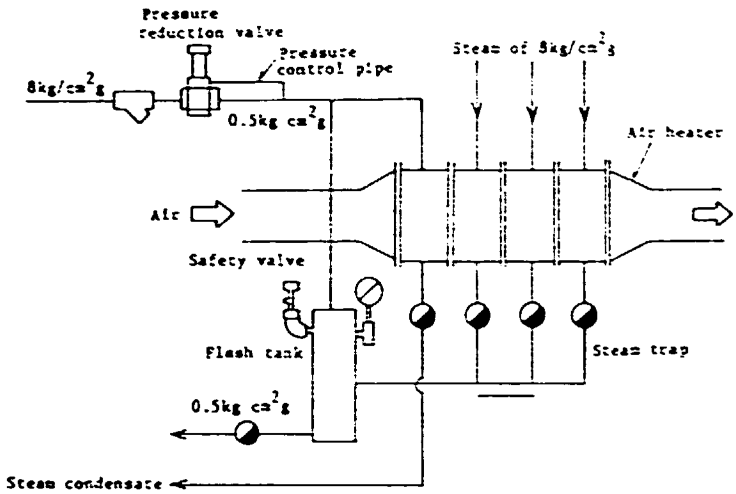


Fig.3.9 Example of Use of Flashed Steam

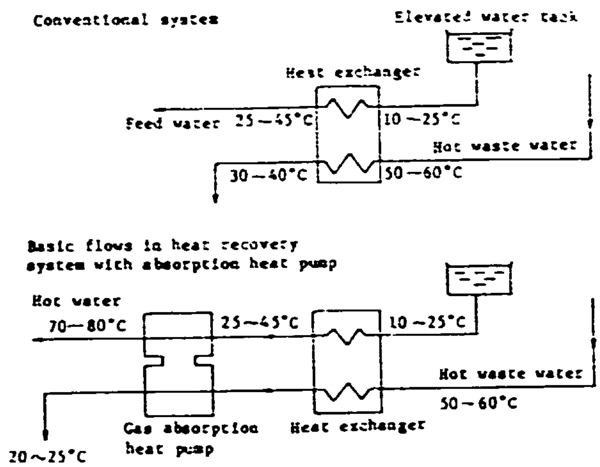


Fig.3.10 Waste Heat Recovery Using Heat Pump