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INTRODUCTORY GUIDEBOOK

OF

CLEANER, SAFER AND ENERGY-SAVING TECHNOLOGIES

V.92-55558

This document has been prepared by Mr. Tadaharu Ito, UNIDO consultant, under the guidance of the Industrial Technology Promotion Division. Please address any queries to the Director of this Division.

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Introduction

Energy saving is important not only for the improvement of productivity in the industrial processes but also for environmental protection from the global point of view.
The largest energy consuming sector in the developed coutries is industry with about 40 % in average(37 % in USA and 45 % in Japan for instance), folloewd by the transport and residential/commercial sectors(20-30 % each).
On the other hand, the overall energy consumption in the developing countries is very small in the absolute amount as well as specific consumptin per person, though the efficiency of energy usage is generally low compared with that in developed coutries.
Enegy consumption in the developing coutries is expected to increase rapidly in the future in line with their industrial development. Therefore, more efficient usage of energy should be promoted intensively in the developing coutries, introducing and applying energy saving technologies so as to meet their own conditions. This guidebook was prepared to give some help and suggestion for ensuring that energy-saving technologies are applied as succesfully as in developed coutries.
Due to the restriction of volumes, this guidebook had to cover only the steel, cement and pulp/paper industries. The other industries such as foundry, fertilizers, petro-chemicals and textiles are expected to be handled in the future.
One of the most advanced countries from the point of energy saving as well as environmental protection for the industrial sector is Japan. This guidebook, therefore, handles mainly such technologies which have been developed and applied succesfully in Japan.
Energy saving in the industrial sector is, in general, achieved in three ways, i.e., modification of process and equipment, waste heat recovery and operational effort. The operational effort is not treated in this guidebook, but its importance should be always recognized. The operational modification for energy saving is expected to obtain a good result mostly when it is promoted as one of the total quality control (TQC) management by the operaters and staffs at each production place. Each contribution of the operational effort to energy saving might be samll and not sensibly measured. However, the accumulation of each effort produces a great result which contributs to the final efficiency of energy consumption.

CONTENTS

A. Energy saving in the Steel Industry

Some comparisons of energy consumption and recovery per ton of crude steel produced in major steel producing countries reveal that Japan is the best, followed by West Germany as shown in the following table.

	Specific energy consumption(1989)	Energy recovery(1989)
Japan	100	33.4 %
West Germany	107	31.9 %
France	114	21.1 %
Brasil	116	25.8 %
United Kingdom	117	27.0 %
USA	135	14.6 %

Note : The unit of specific energy consumption has an index of 100 in Japan.
The values of specific energy consumption are adjusted for comparison under the same production ratio of pig iron to crude steel in Japan.
Energy recovery means the percentage of energy recovered to energy input.
Source : The Japan Iron and Steel Federation's estimation from IISI data

The specific energy consumption in Japan is expected at about 4.40 x 10^6 kcal (18.4x10^6J)per ton of crude steel in 1990. This value is 20 % less than that in 1973.
Such notable progress has been achieved through the implementation of energy saving measures from various angles including equipment, process and operation since the first oil crisis of 1973.
The present state of energy consumption and recovery in Japanese steel industry is as follows.(Source:Japan Iron and Steel Federation)

·Energy source (in 1990):

Coal	78.1%
Oil	7.8%
Purchased electricity	14.1%
Total	70.3x10^6 ton of coal equivalent

·Waste energy recovery in integrated steel works (in 1990):

Coke dry quenching	45.0%
Top pressure recovery turbine	29.7%
Others	25.3%
Total	2.63x10^6 kl of oil equivqlent

·Specific consumption of oil and electricity(1990)

	Integrated steel works	Ordinary steel EAF plant	Special steel EAF plant	Ave.
Oil(l/t-steel)	28	37	93	38
Electricity(kwh/t-steel)	506	550	883	595

		1973	1987
·Blast furnace fuel consumption (kg/t-pig-iron)	Coke	440	475
	Heavy oil	53	0
	Tal	6	2
	Pulperized coal	0	33
	Total fuel	499	510
·Gas recovery from basic oxygen furnace(m3N/t-LD steel)		25	104
·Continuous casting ratio(%) =100x(crude steel productin by CC) /(total crude steel production)		22	93
·Electric arc furnace production ratio		18.0	28.4(1983)

Energy-saving measures taken by the steel industry break down into three groups:

(1) Introduction of highly efficient equipment and improvement of operational techniques.

(2) Elimination and concatenation of production processes.

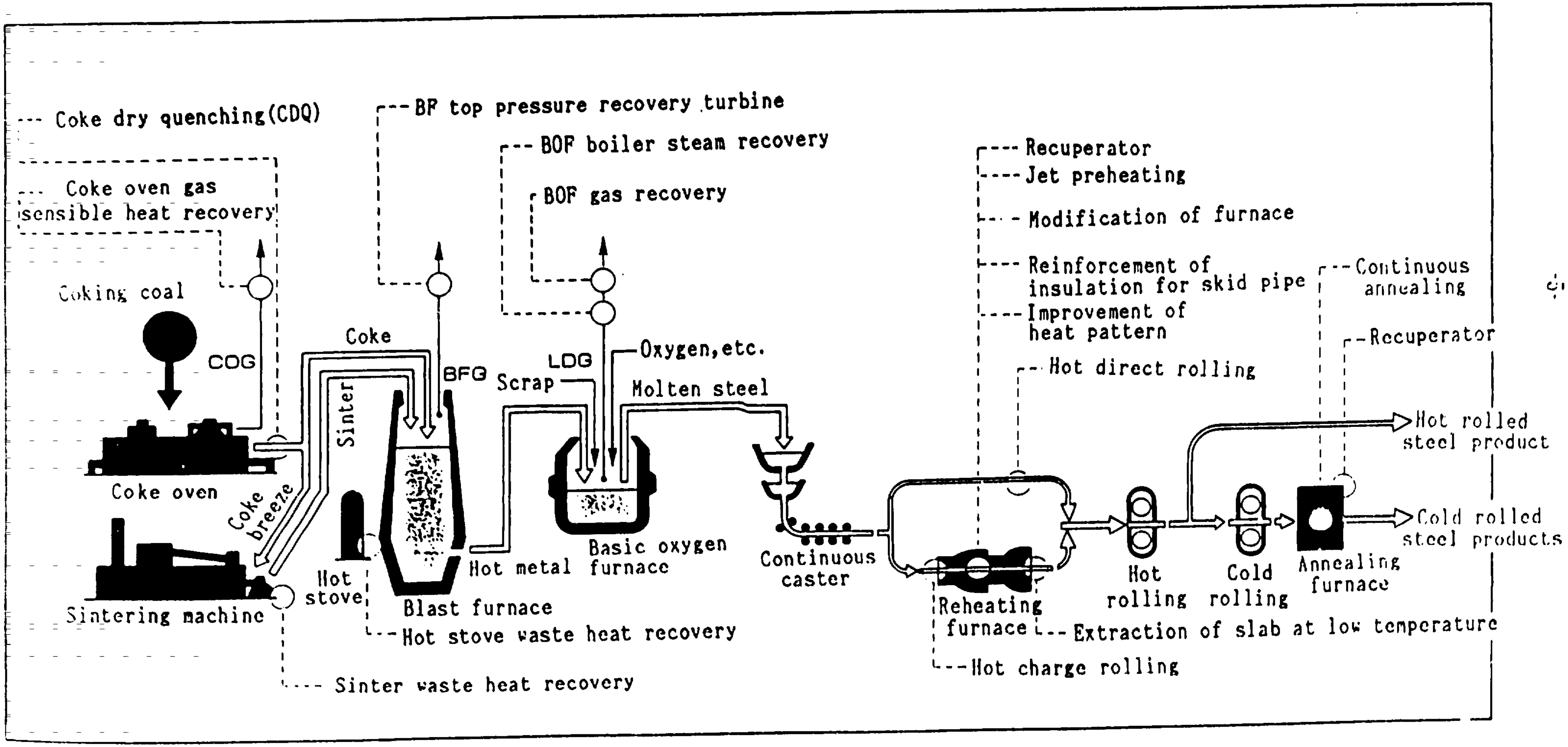
(3) Recovery of waste energy.

Specific measures taken for each process are illustrated in the following diagram for the integrated steelmaking.

For the steelmaking by electric arc furnaces, the following items have been introduced for energy saving.

- Oxygen injection
- Carbon injection
- Ladle furnace refining
- Capacity-up of the furnace
- Ultra-high power(UHP) transformer
- Water-cooled panel
- Water-cooled wall
- Scrap preheating
- Clean house(dog house) dust collection
- Direct current arc furnace

Energy Saving Measures in Integrated Steel Works



A1. Energy Saving in the Sintering Process

(1)General

Energy consumption in the sintering process amounts to as much as 10 % of total energy consumption in integrated steel works.
A typical heat balance of the sintering procces is shown below.

Input 450 x 10^3 kcal/t		Output 450 x 10^3 kcal/t	
Combustion heat of coke	79.6 %	Cooling heat of sinter	32.6 %
Combustion heat in ignition furnace	8.8	Sensible heat of main flue gas	15.8
Combustion heat of dust	6.8	Decomposing heat of limestone	12.5
Others	4.8	Vaporizing heat of water	12.4
		Decomposing heat of crystalized water	6.1
		Sensible heat of sinter	5.9
		Others	14.7

For the improvement of energy saving in the sintering process, both directions of the waste heat recovery and the reduction of energy consumption unit should be explored at the same time. The main items of those which have been developed and iontroduced to sintering plants are listed below.

Reduction of energy consumption unit

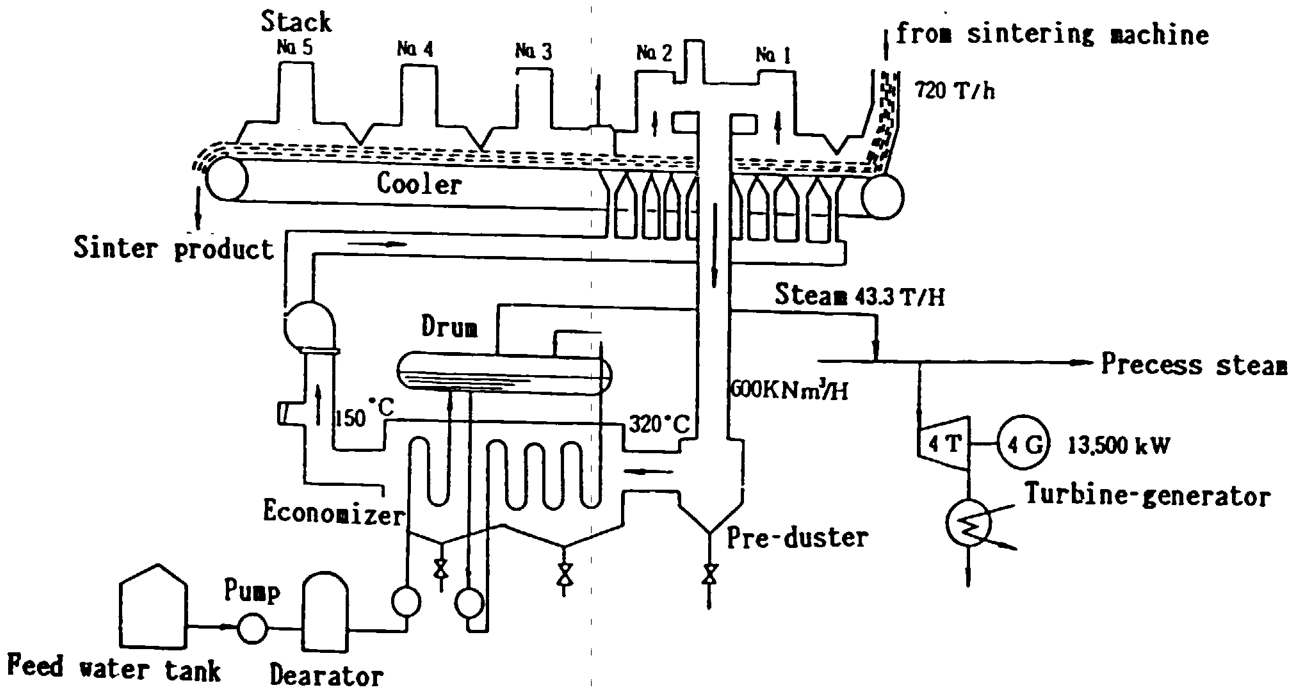
- ·Coke consumption unit ----- Improvement in combustion effiency of coke breeze
- ·Sinter yield -------------- Improvement in permeability of sintering bed
- ·Fuel consumption ---------- Usage of flue gas from the cooler as combustion air for ignition furnace
- ·Main flue gas fan --------- Introduction of high efficiency fan
  Speed-controled fan
  Minimizing of leakage

Waste heat recovery

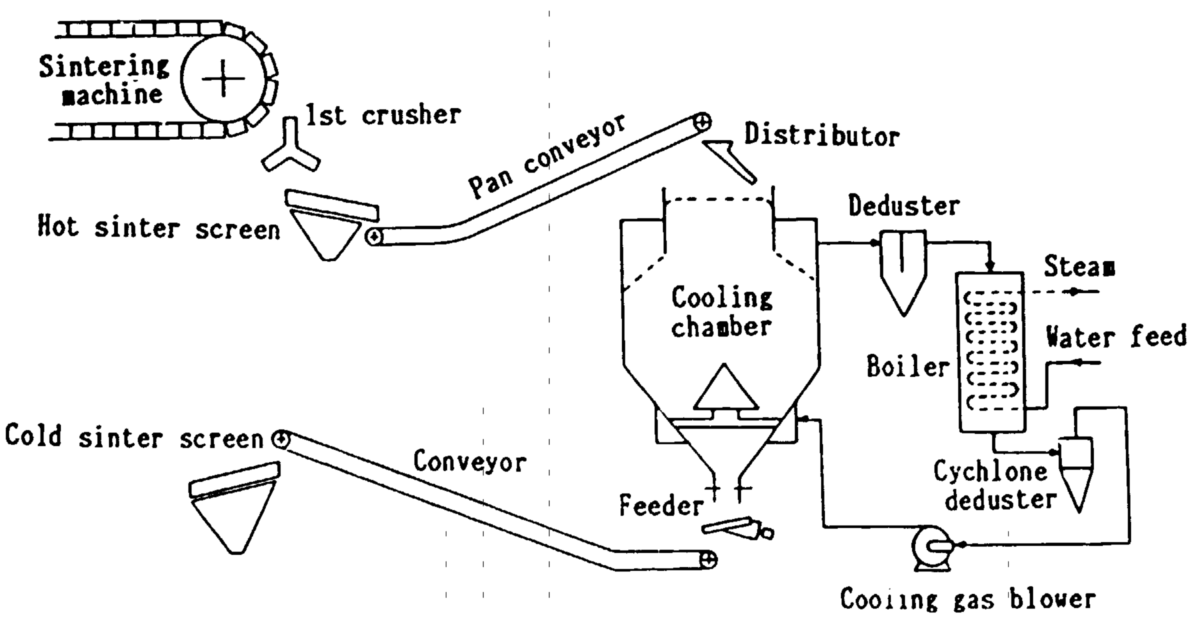
- ·Heat recovery from the cooler
  ex. Flue gas temperature : 400℃→150℃ with steam generation(14atg,270℃)
- ·Heat recovery from the main flue gas
- ·Heat recovery from the produced sinter(Shaft furnace type)

(2)System flow chart

Two different types of heat recovery system are shown below.



An example of heat recovery system from sinter



An example of heat recovery systen fron sinter (Shaft cooler type)

A2. Coking Coal Preheating

(1)System description

It is well known that the charging of preheated coal into a coke oven improves the quality and productivity of coke because of the increase of charging density and the decrease of water content. The following three processes are available on a commercial basis.

	COALTEK PROCESS	PRECARBON PROCESS	THERMOCHARGE PROCESS
Developer	Allied Chemical	Bergbau Forschung Didier Engineering	Otto-Simon Carves
Preheating medium	Steam	Combustion gas	Combustion gas
Preheater	Single stage Flash type Inner impactor	Dobble stage Flash type	Dobble stage Flash type
Charging of preheated coke	Pipe charge by steam	Gravity charge by chain conveyer and chute car	Gravity charge by charging car

The preheated temperature of coke is about 200 C in any case of these processes.

(2)Merits of the system

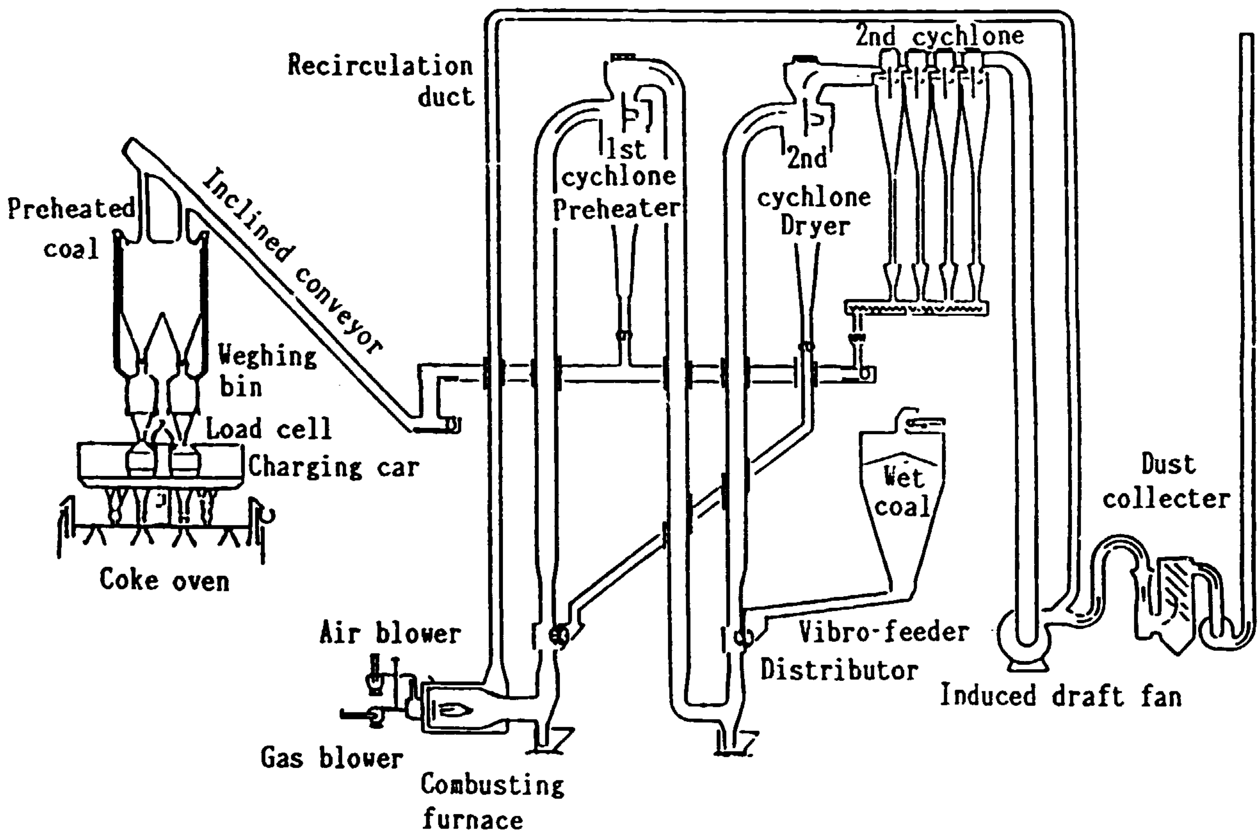
- ·Improvement of charging density in coke oven 10 - 14 %
- ·Reduction of carbonizing time in coke oven appr. 20 %
- ·Improvement of coke oven productivity 35 - 40 %
- ·Reduction of coke oven fuel consumption appr. 13 %

(3)Construction record

All of three types have been constructed in Europe and United States.
Pre-carbon system was constructed in Japan and has been in operation since 1979.

(4)System flow chart

The flow diagram of the Themocharge process is shown below for example.



A3. Coke Dry Quenching (CDQ)

(1) System description

The hot coke pushed from the coke oven gas has plenty of sensible heat. Conventionally, coke was cooled with water, without recovering the sensible heat. With CDQ equipment, this sensible heat is recovered as steam, which is used as an energy source for such purposes as electricity generation and reheating.

The CDQ equipment consists of the following parts.

1) Hot coke conveying and charging equipment
2) Coke quenching equipment
3) Cold coke discharging and transporting equipment
4) Cooling gas recirculating equipment
5) Dust collecting equipment
6) Waste heat boilor
7) Micellaneous facilities

The hot coke is cooled in the quenching chamber from 800-1000°C to 200°C by contact with cooling gas (N_2), which recirculates between the quenching chamber and waste heat boilor. The pressure of cooling gas is +240 mm Aq at the inlet of the chamber, -20 mm Aq at the outlet and -400 mm Aq at the inlet of the gas recirculation fan.

The system is operated continuously, except for the charging of coke.

(2) Merits of the system

1) The amount of steam recovered from one ton of coke is generally about 0.44 ton, or equivalent to 35 liters of fuel oil.(Heat recovery efficiency is about 85%). Recently. such high heat recovery rate as 0.55 t-steam/t-coke has become normal as a result of further improvement such as discharging gas recovery, sub-economizer after boiler and so on.
2) The quality of coke is improved in contrast to the wet type quenching.
3) The operation of the blast furnace is stabilized because of zero water content.
4) The problem of dust emission and scattering is solved because of the closed-circuit system of the cooling gas.

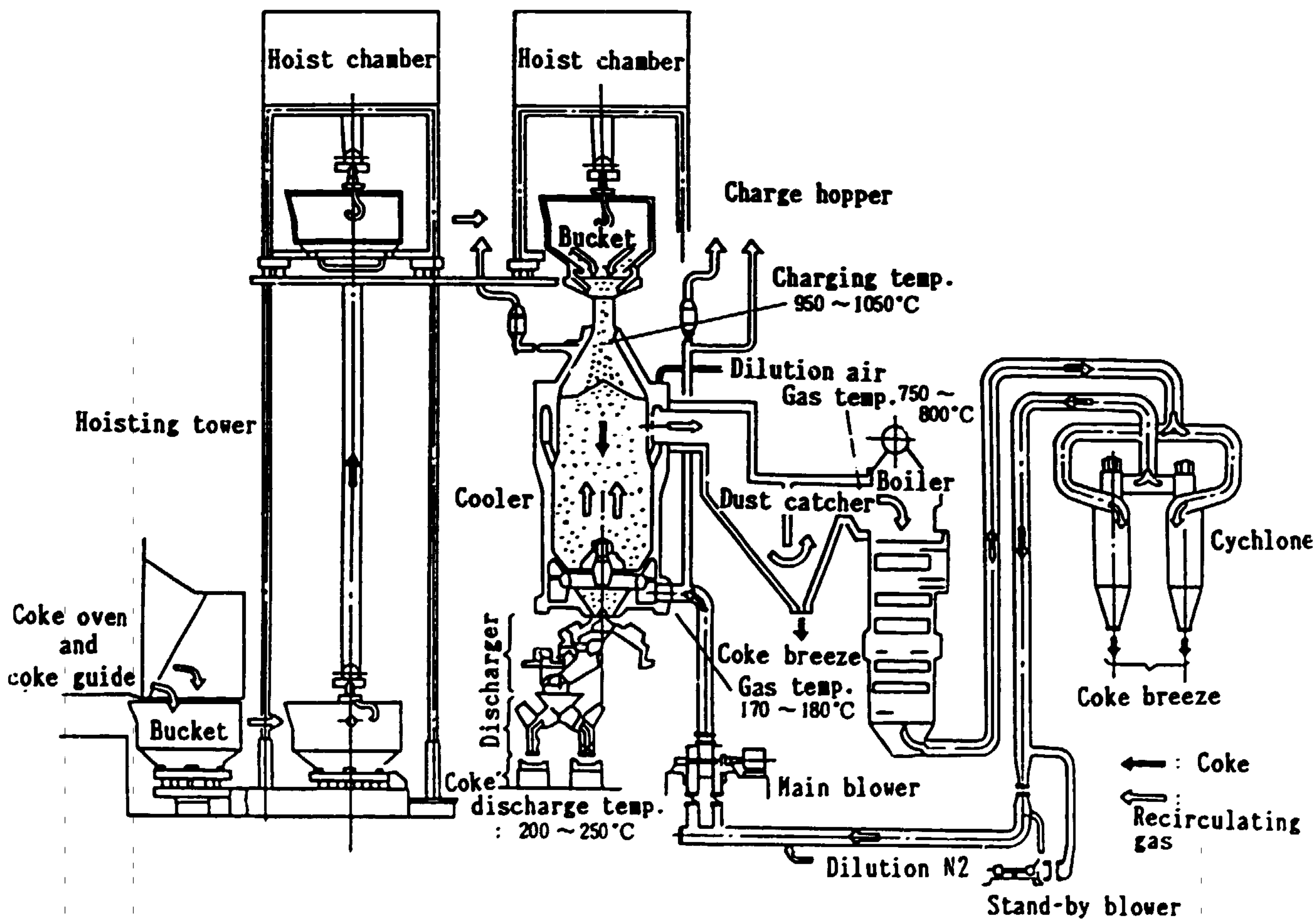
(3) Construction record

CDQ equipment has been installed at more than 70 % of all coke ovens in the steel industry in Japan and reached 34 units in 1990.

(4) Supplier

Nippon Steel Corpration, Engineering division
NKK Corporation
Ishikawajima-harima Heavy Industries,ltd(IHI)

(5) System flow chart



A4. Heat Recovery from Hot Stove

(1)System description

The temperature of the combustion gas from hot stoves is generally less than 350°C and its average ranges from 200 to 250°C. Two methods to utilize the recovered heat have been developed, one is to produce electricity using some medium of low boiling point to drive the turbine generator, and the other is to utilize the recovered heat for the preheating of combustion air and fuel. The former produces a more valuable product of electricity but is much more complicated compared with the latter.

For the heat exchanger, the following types are available.

- ·Rotary type (Jungstrom, Rotemeule)
- ·Plate type
- ·Heating medium recirculation type
- ·Heat pipe type

<u>Example of Jungstrom type</u>

Heating gas	420,000 m^3N/h, 150-250°C(Ave.200°C)
Air to be preheated	260,000 m^3N/h, 15°C → 150°C
Heat exchange area	6,400 m^2 in 6.7 mϕ x 1,200 mmH
Rotating speed	1-4 rpm
Ave. gas velocity	8-16 m/s
Pressure loss	25-100 mm Aq.

In case of this type, considerable amount of air leakage from cooling side to heating side is unavoidable.

<u>Example of heating medium recirculation type</u>

Heating gas	less than 350°C
Air to be preheated	197,000 m^3N/h, 20°C 120°C
Fuel gas to be preheated	147,000 m^3N/h, 30°C 120°C
Pressure loss	30-80 mmAq. for one heat exchanger
Heat exchanger	Fin-tube type, Tube:STB, Fin:Alminium
Heating medium	Ethyl-diphenel, Boiling point:340 C

(2)Expected effect

By preheating air and fuel for hot stoves, the consumption of high calorie gas such as COG or LPG, which is mixed into the hot stove fuel gas, can be reduced. The expected energy saving is about 50 to 90 kcal/m^3N-hot stove fuel gas.

(3)Construction Record

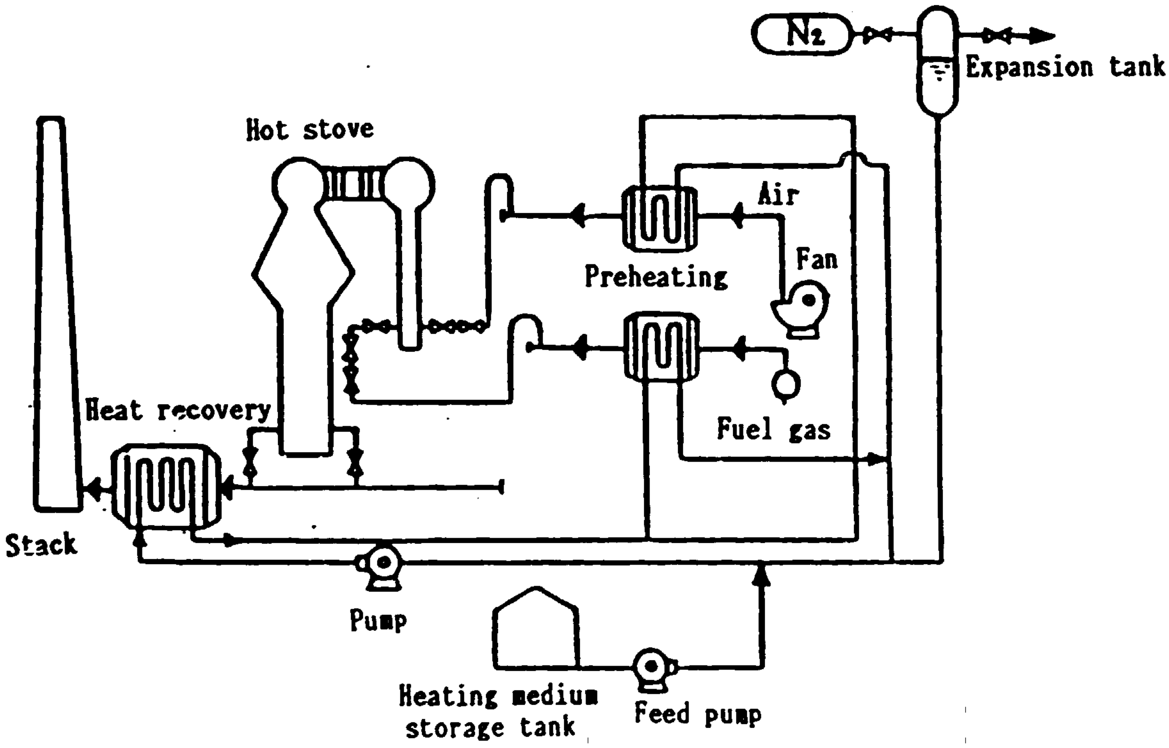
Heating medium recirculation type : More than 10 units in Japan and Korea
Rotary type : Many

(4)Supplier

Nippon Steel Corporation, Engineering Division

(5)System flow chart

The system flow diagram of heating medium recirculation type is shown below.



A5. Top Pressure Recovery Turbine (TRT)

(1) System description

To enhance their productivity, blast furnaces are generally operated under high pressure. Formerly, this pressure was reduced by a regulating valve without recovering any pressure energy of the exhaust gas. TRT system recovers this energy, producing electricity.

TRT system consists of dust removing equipment, turbine-generator unit, control units, ducts and valves.

The technically important specifications are as follows.

1) Turbine efficiency at the design point is around 83-87 %, using a low gas velocity multi-stage reaction turbine of free vortex blade.
2) Allowable dust and free mist content for the turbine is up to 30 mg/m³N and 30 g/m³N respectively.
3) The rated speed is chosen lower than the first critical speed of turbine roter so as to avoid vibration problems.
4) A non-contact type mechanical seal is applied to ensure a perfect gas seal during operation while consuming a small amount(60 m³N/h) of sealing medium such as N_2 gas or compressed air.
5) An automatic nozzle(1st stationary blade) control system is applied to regulate the turbine speed and the top pressure or turbine inlet pressure at wide range gas flow, improving the recovery of energy.

For the dust removing system, wet type scrubbers(wet system) have been conventionally applied. However, the dry type(dry system) was recently developed and its introduction has started to replace the wet system.

The features of the dry system are as follows.

1) Increase in electricity generation
2) Increase in heat value of recovered blast furnace gas
3) Decrease in water consumption
4) Solid-water separation system is not necessary.

(2) Merits of the system

TRTs have an output of about 10,000 kw each, the largest units boasting a 20,000 kw output. Electricity generated by TRTs in Japan totals 3 billion kwh a year, 8% of the electricity used by integrated steelworks.

(3) Construction record

All blast furnaces in operation in Japan are equippd with a TRT, totaling over 36 units in 1990.

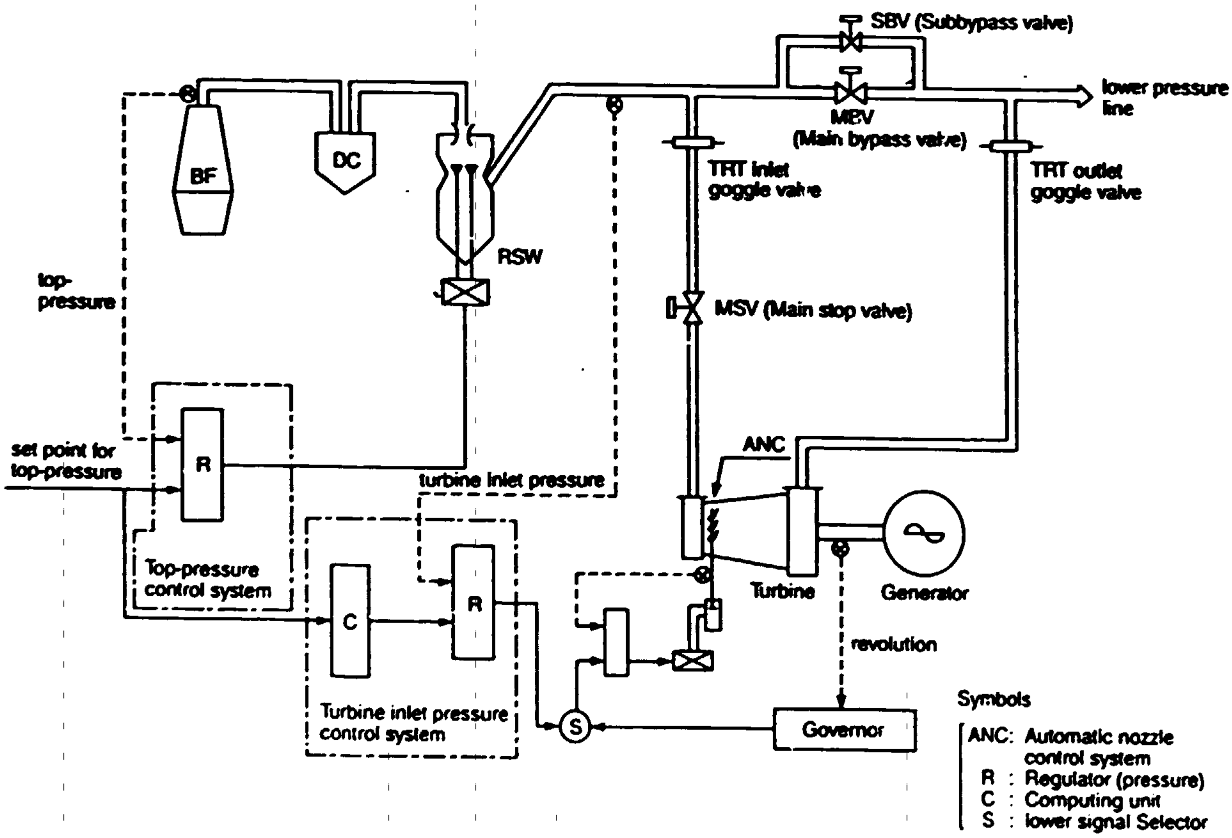
(4) Supplier

Hitachi Zosen Corporation
Kawasaki Heavy Industries,ltd

(5) System flow chart

Diagram of BF gas flow and Control system TRT arranged in series to RSW

RSW:Ring slit washer



A6. BOF Gas Recovery System

(1)System description

Various kinds of systems have been developed and applied to treat the BOF gas as shown below.

Combustion type --------- Full boiler system
Half boiler system
Water-jacket system
Non-combustion type ----- OG system
IC system
Dry ESP system

The non-combustion type has the following advantages over the combustion type.

- The cooling and dust removing equipment is smaller because of lower gas temperature(1,600°C), smaller gas volume and larger particle size.
- The recovered gas(CO:>90%) can be utilized as fuel.

Much attention should be paied to the sealing and leakage of gas in case of non-combustion type, especially for connecting parts of lance guide and lime chutes

The necessary pressure difference to be generated by induced draft fan is about 1,600 mm Aq in case of OG system. On the other hand, it is only 750 mm Aq and 700 mm Aq in case of IC system and dry electric precipitator system respectively because these use dust collectors of low pressure loss type.

Among those systems, gas recovery systems(non-combustion type) using wet scrubbers (OG and IC) have been most preferably installed in the modernized integrated steel works.

In the OG system, the skirt is set down onto the converter mouth during the refining in order to shut out the atmospheric air. The BOF gas generated from the converter is cooled to about 1,000°C at the upper hood and radiation cooler, and then the dusts are removed by the first(solid throat) and second(variable throat) Venturi scrubber. The dust concentration is redudced to less than 0.1 g/m^3N at the outlet of the second scrubber.

The BOF gas is sent to the gas holder by an induced draft fan. At the initial and final stage of refining, the BOF gas is sent to a flare stack for combustion discharging because of its poor content of CO.

In order to cope with the stringent regulation for the dust emission, the pressure difference generated by the fan has been increased, sometimes as high as 2,000 mm Aq, and if necessary, a silencer is provided after the fan to reduce the noise.

(2)Expected merits

The recovery rate of the BOF gas is as much as 80 m^3N/ton-steel, that coresponds to 160,000 kcal/ton-steel with the heat value of 2,000 kcal/m^3N-BOF gas.

(3)Construction record

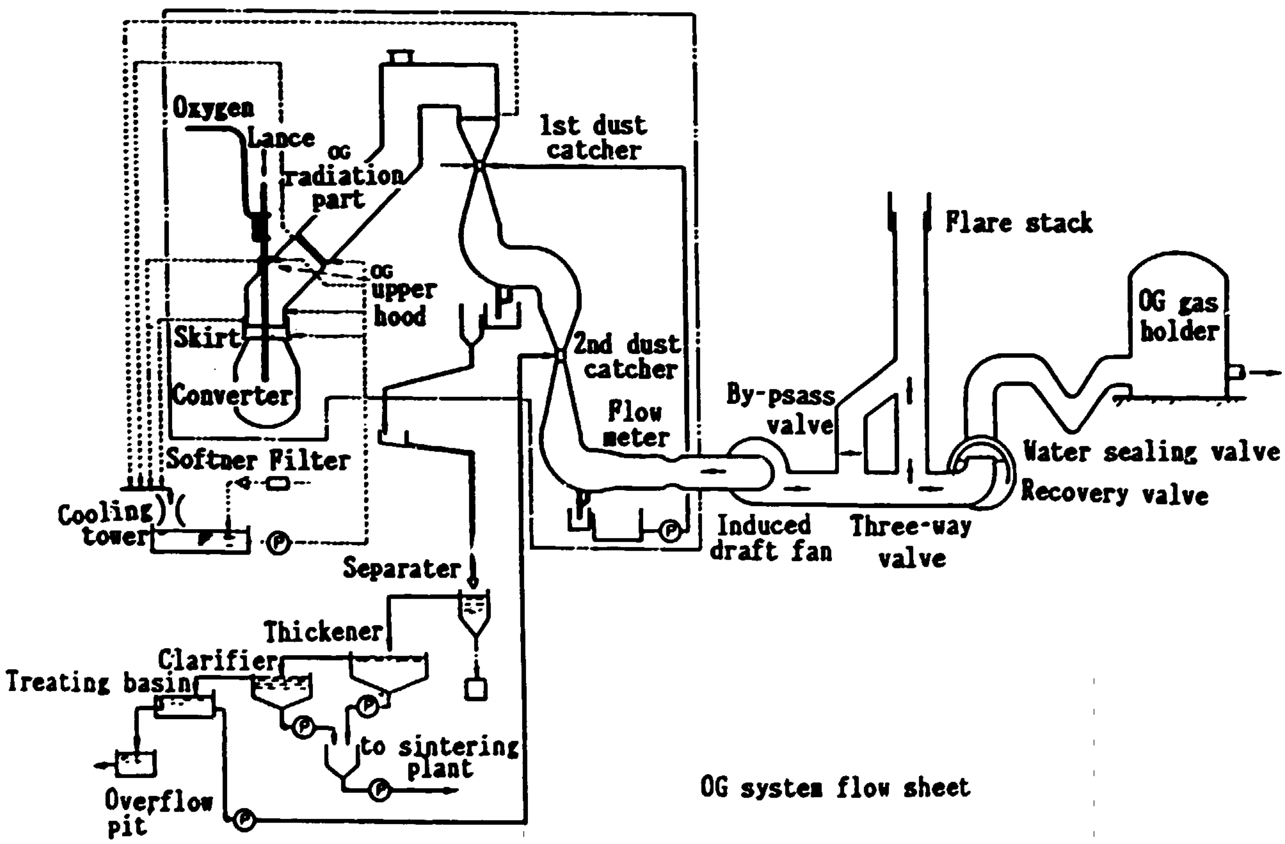
Almost all the BOF in Japan are equipped with gas recovery system.
Tne number of the units in 1984 is as follows.

OG system	68 units
Full boilor	7 units
Half boilor	7 units

(4)Typical supplier

Kawasaki Heavy Industries,ltd
Nippon Steel Corporation

(5)System flow chart



OG system flow sheet

A7. Direct Current Electric Arc Furnace(DC EAF)

(1)System description

The direct current electric arc furnace(DC EAF) consists of the following equipment.

- ·Circuit breaker for DC EAF
- ·Transformer for dropping the alternating voltage to feed the thyristor rectifier
- ·Thyristor rectifier to convert the alternating current to the direct current
- ·Direct current reactor to protect the thylister rectifier from the over current at the short circuit
- ·Bus bar and water-cooled cable connecting the direct current reactor with carbon electrode and bottom electrode
- ·Carbon electrode(+) and bottom electrode(-) for feeding the electricity to the furnace
- ·Harmonic filter to compensate the harmonic generated by the thyristor

The DC EAF applies the single electrode system, which has following features in comparison to the three electrodes system of the conventional AC EAF.

- ·The equipment around the furnace is simple because of the single unit of lifting device, holding arm and water cooled cable for electrode.
- ·The control system of electrode position, arc current and voltage is also simple because of single electrode system.
- ·The water cooling of the top panel is easy.

The DCEAF has a solid electrode at the furnace bottom in order to generate the electric arc between the carbon electrode and the scraps or molten steel. This bottom electrode consistes of a large number of steel rod, called contact pins, penetrating the bottom refractory and fixed on a plate called the conducting disc. The lower side of the contact pins are cooled with forced draft air. Contacting with molten steel, the tops of the pins melt out but solidify again in the pin holes of bottom refractory when the temperature goes lower. That is, the consumption rate of pins and refractory is the same.

The DC EAF applies the following independent control system of electric current and voltage which ensures automatic re-starting by means of the current restriction by thyristor rectifier even in case of short circuit in the furnace.

- ·The arc current is controlled at a set point through the phase angle control on the thyristor rectifier.
- ·The arc voltage is kept at a set point through adjusting the arc length by lifting and lowering of the carbon electrode.

Because of the single electrode system, the melting of scraps by DC EAF proceeds more homogeneously without hot or cold spots as is sometimes the case in AC EAF.

Therefore, the thermal efficiency is improved and noise generation is supressed in case of DC EAF.
The operation of DC EAF is carried out by what is called hot heal process, which retain 10 % of molten steel at the bottom and charge scraps on it in order to keep their electric conductivity with the bottom electrode.

(2)Merits of DC EAF

The advantage of DC EAF as compared to the conventional AC EAF is summarized as follows.

- ·Electrode consumption is reduced to a half.
- ·Electricity consumption is reduced by 5 to 10 %.
- ·The consumption of injection castables is reduced by about 30%.
- ·The flickering is reduced to a half.
- ·The noize generation is remarkably reduced.
- ·The agitation of molten steel is improved.
- ·The heating capacity is increased.
- ·The automatic control is easy.

The following is a relative comparison between conventional AC EAF and DC EAF converted from the AC EAF.

	AC-EAF	DC-EAF
Electrode consumption	100	47
Electricity consumption	100	95
Tap-to-tap tome	100	100
Injection consumption	100	70

The total construction cost for DC-EAF is 150 to 170 % of that for AC-EAF. If the cost of flicker-compensation device is taken into consideration, the difference is expected to be smaller than the above-mentioned.

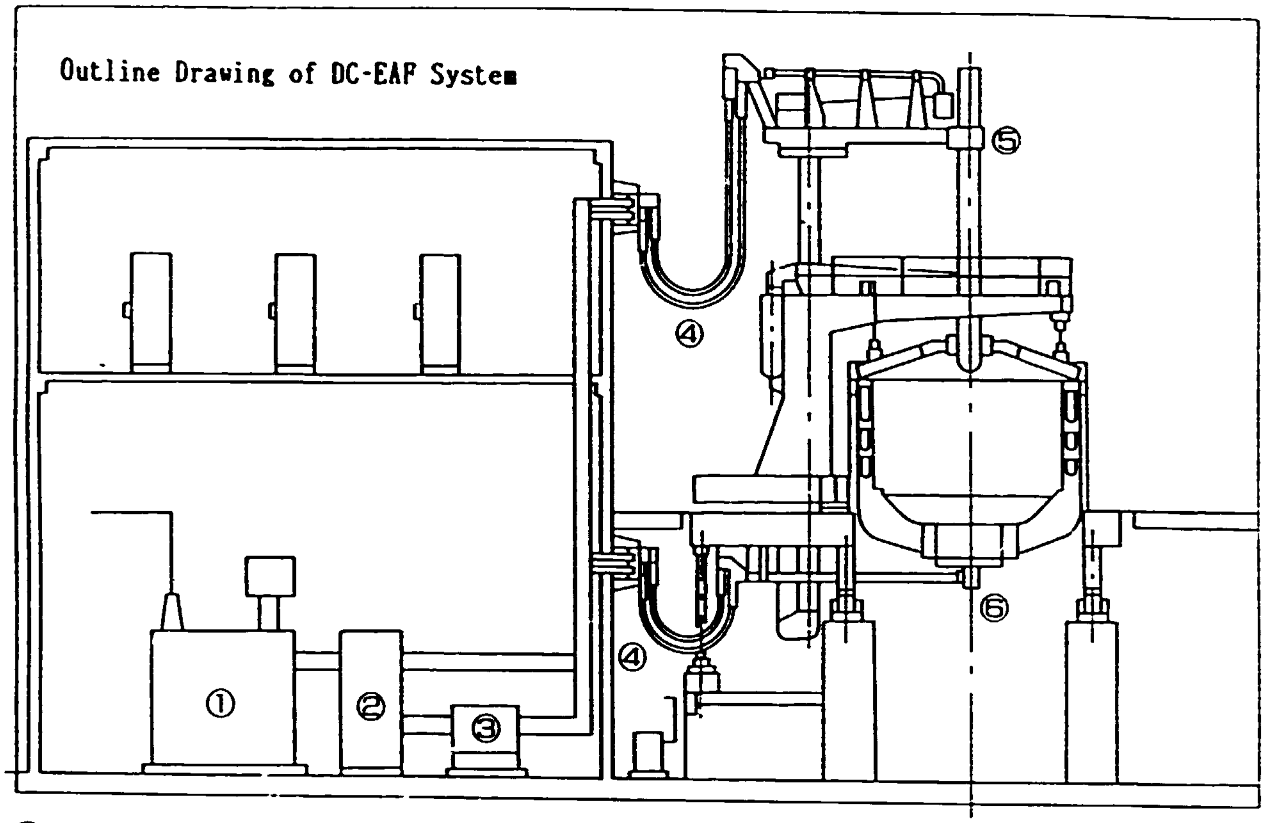
(3) Construction record

More than 5 furnaces from 30 to 130 ton are in operation or under construction in Japan and Korea.

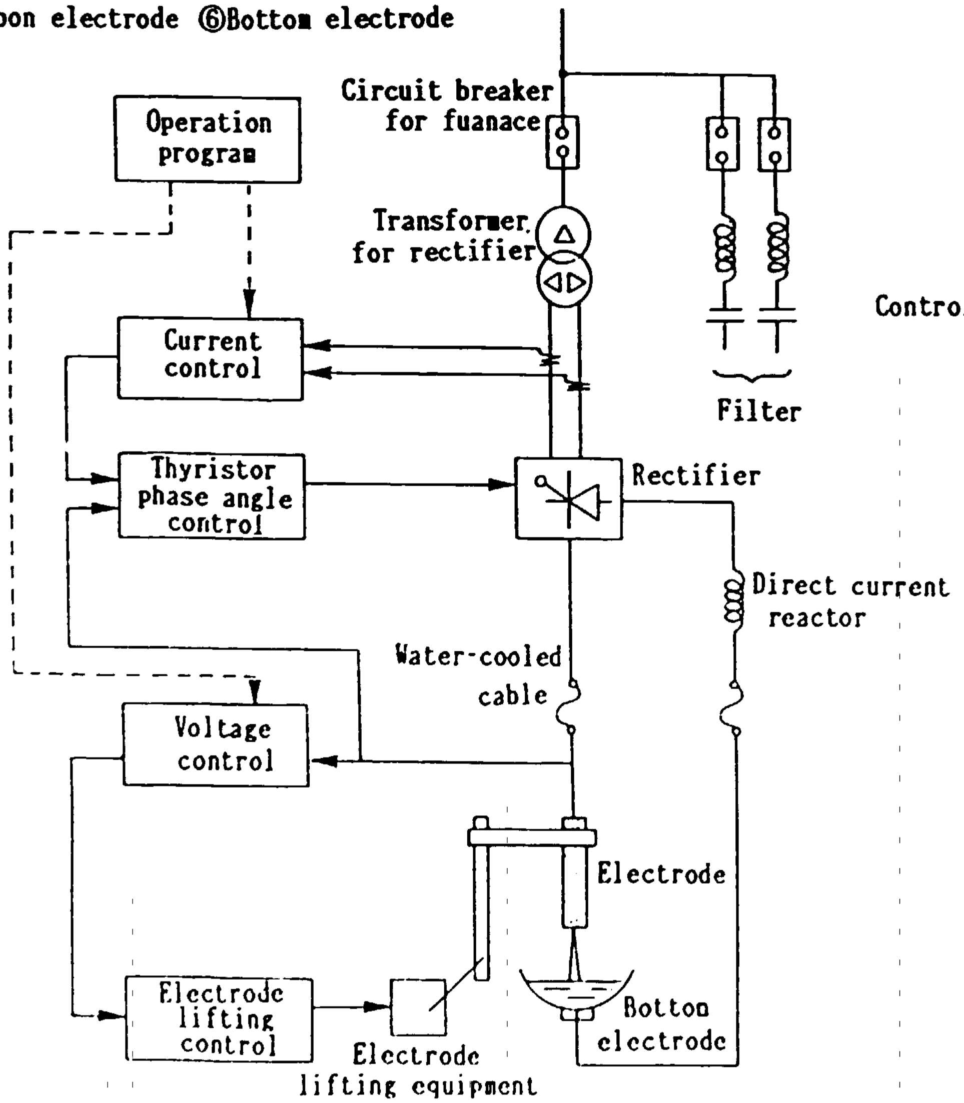
(4) Supplier

MAN·GHH, Germany
NKK Corporation, Japan
CLECIM,France
Acea Brown Boveri
Ishikawajima-Harima Heavy Industries, ltd
Nippon Steel Corporation - IRSID

Outline Drawing of DC-EAF System



①Transformer ②Thyristor rectifier ③Direct current reactor ④Water-cooled cable
⑤Carbon electrode ⑥Bottom electrode



Control System

A8. Scrap Preheater for Electric Arc Furnace

(1)System description

A typical energy saving measure taken at electric arc furnace shops is waste heat recovery by means of a scrap preheater for the electric arc furnace. High -temperature waste gas is generated when an electric arc furnace smelts scrap using an electric arc. The scrap preheater uses the heat of this waste gas to preheat the raw material scrap to about 300°C.

The operation of the scrap preheater is carried out automatically except for setting and lifting of scrap backets. The most important matters to be considered to introduce this system are the matching with the electric arc furnace operation and the sealing at the connecting parts.

Several variations are available for this system as shown below.

- Backet preheating system ------ Scrap is preheated in the scrap backet.
- Preheating chamber system ----- Scrap is preheated in the preheating chamber and then discharged into the scrap backet.
- One through system ----------- The hot gas flow once through the scrap.
- Recirculation system --------- The hot gas recirculates between the scrap and a combustion chamber, where the gas generated at scrap preheating is incinerated.

(2)Merit of the system

The scrap preheater reduces not only the electricity consumption and refining time but also the electrode and oxygen consumption.

The expected effect depends on the furnace operation, scrap conditions, gas conditions and preheating time. The following are the typical expected effects based on some operational experiences with scrap preheaters.

Saving of electricity consumption	20 - 50 kw/t-steel
Decrease of operation period	3 - 8 min
Saving of elctrode consumption	0.2 -0.5 kg/t-steel
Saving of oxygen consunption	4 - 6 %

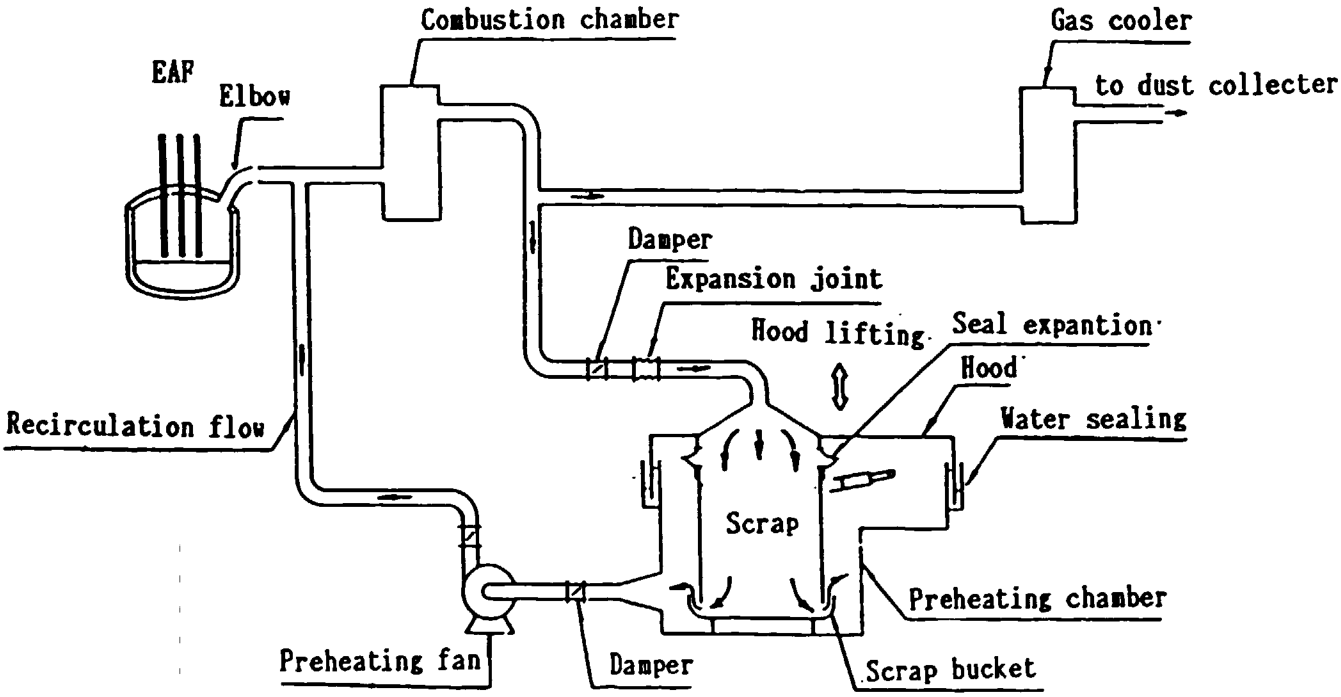
The scrap preheater also reduces the risk of unexpected explosion in the electric arc furnace due to the water carried by the scrap.

(3) Typical supplier

NKK Corporation
Nippon Spindle Co.
Nikko Engineering Co.

(4) System flow chart

An example of the backet type, recirculation system is shown below.



A9. Clean House (Dog House) System for Electric Arc Furnace

(1)System description

The clean house system was developed originally to solve the problem of dust and noise emitted from the electric arc furnace, totally enclosing it with a house furnished with movable doors and windows. By this system, the situation was drastically improved. However, this system is effective not only for the dust and noise control but also for the energy saving, because much less quantity of extraction air is required compared with the conventional canopy system.
The clean house is an airtight chamber of welded steel structure lined with rock wool, provided with following openings.

- Charging door for scrap backet passing
- Ceiling door for passage of crane wires
- Front door for furnace operations
- Tapping door
- Hood to extract dust and gas
- Duct connection to induce an amount of air for the temperature control inside the house

(2)Merit of the system

Besides the improvement in dust and noise control, the clean house system has an advantage over the conventional canopy system in both investment and operation cost.
One example of cost estimation is shown below in comparison with the conventional system.

Dust collecting system in case of 200 ton electric arc furnace

Conventional system :

Direct extraction	3,000 m^3/min, 800 mm Aq
Indirect extraction(Canopy hood)	15,000 m^3/min, 300 mm Aq
Clean house system	5,000 m^3/min, 400 mm Aq

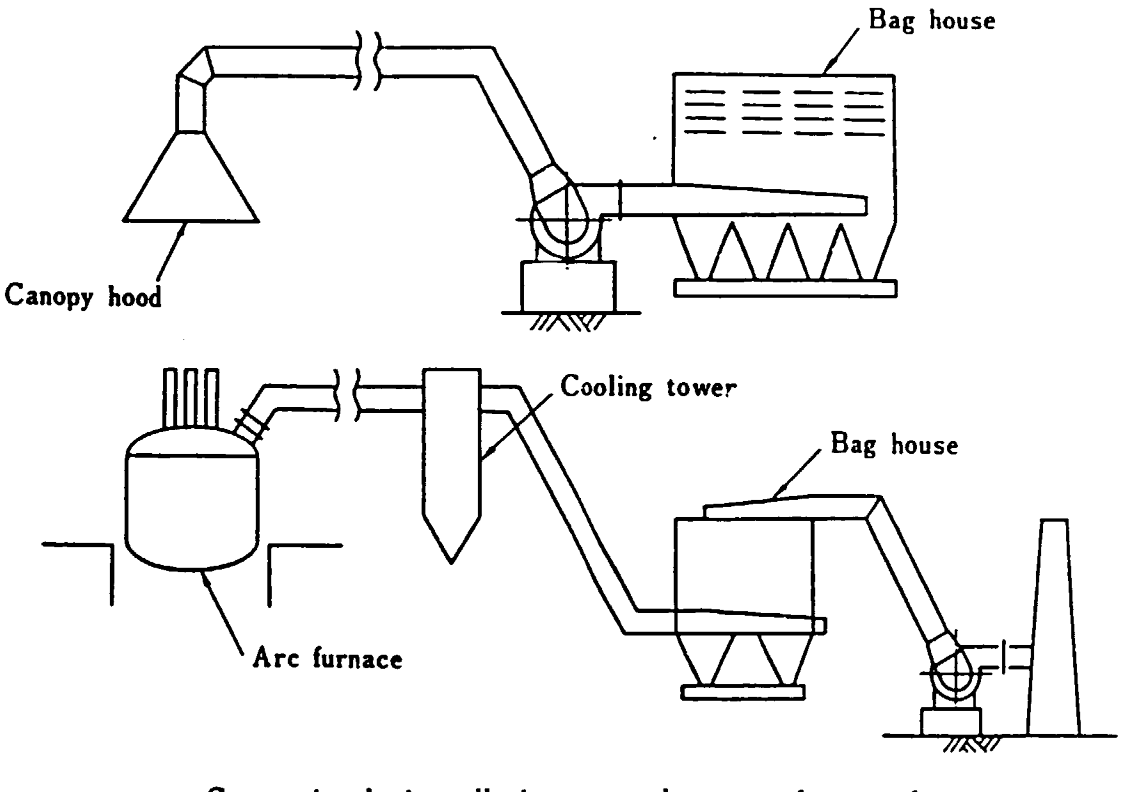
Investment cost 2(conventional) : 1(clean house)

Operation cost 3(conventional) : 2(clean house)

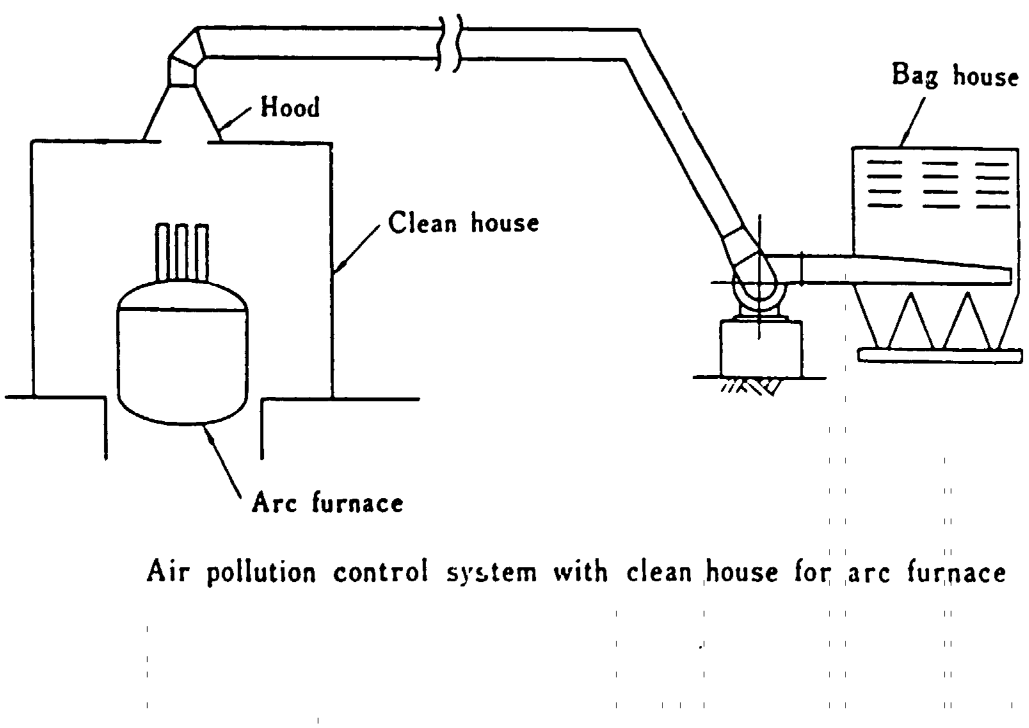
(3)Supplier

Ishikawajima-harima Heavy Industries,ltd

(5)System flow chart



Conventional air pollution control system for arc furnace



Air pollution control system with clean house for arc furnace

A10. Slag Sensible Heat Recovery System

(1)System description

The sensible heat of slag is enormous as shown below.

BF slag 300 kg/t-iron x 1,500°C x 0.28 kcal/kg°C = 126,000 kcal/t-iron
BOF slag 100-150 kg/t-steel x 1,500 x 0.28 kcal/kg°C = 42,000~ 63,000 kcal/t-steel

The most important problem for the development of slag sensible heat recovery system is the selection of a granulating method considering the quality and shape of products required by its usage.
Several numbers of processes have been developed. Some typical processes are described below.

<u>Drop-impacter granulating process</u>

The liquid state BF slag is dropped on a rotating drum and is granulated as slag droplets at impact on the drum. A fluidizing bed system using the water granulated slag as a fluidizing medium is applied in this process. The medium recirculates in the system in order to avoid the adhesion of produced droplets and to improve heat recovery rate.
By direct contact, the waste heat of slag is transfered to the air which recirculates between the product cooler and the waste heat boiler.
The product slag is of high quality for fine concrete aggregate.

<u>Air granulating process</u>

In order to granulate BOF slag, an amount of high speed air jet is injected into the slag. By this method, the product quality is much improved at the point of swelling collapse, which has been one of the defects of BOF slag.
The waste heat of slag is recovered to generate steam by direct contacting tubes located in the product, and also by the radiation tubes arranged over the product.
The waste heat of granulating air is also recovered to dry wet mill scales.

(2)Expected merits

The expected heat recovery rate is 50 to 70 %.

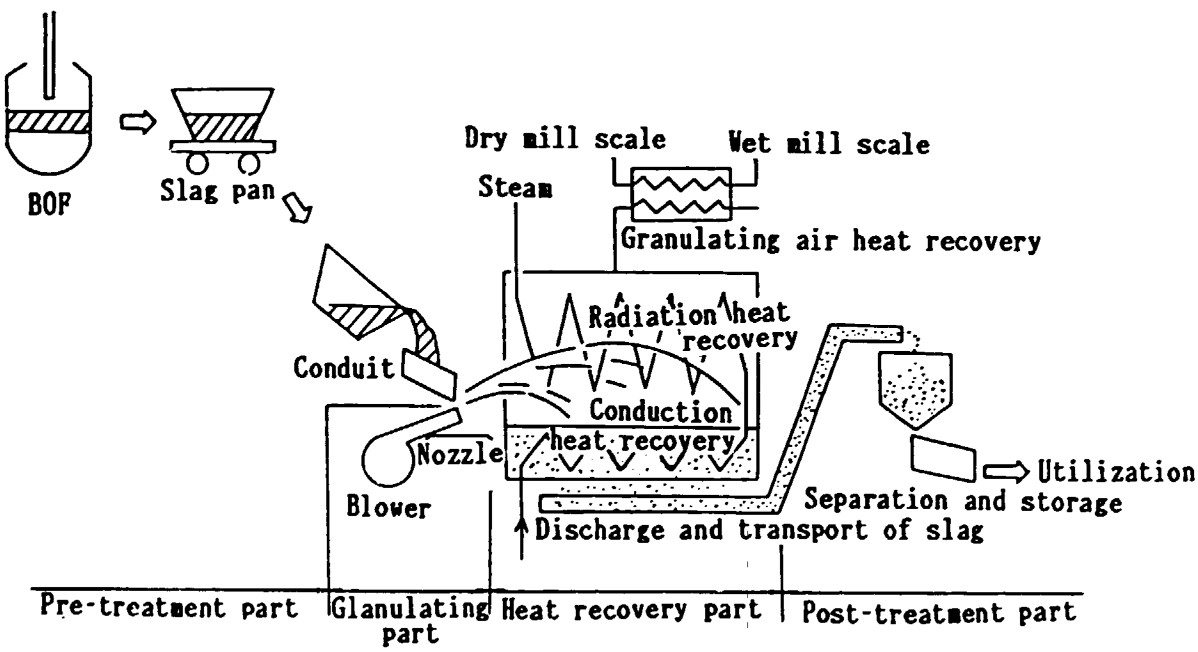
(3)Construction record

A considerable number of different heat recovery systems were constructed and operated for development and demonstration in Japan, and some of which were successfully commercialized. A plant of heat recovery system from BOF slag was constructed in Fukuyama Steel Works, NKK Corporation in Japan and has been operated since 1981.

(4)Supplier

Ishikawajima-harima Heavy Industries, ltd
Mitsubishi Heavy Industries, ltd
Nippon Steel Corporation

(5)System flow chart



BOF slag granulating system

A11. Energy Saving for Reheating Furnace

(1)General description

The energy consumption at reheating furnaces is as much as about 70 % of total energy used for the rolling process, which uses about 10 % of total enegy input into the integrated steel works. Considering such importance of reheating furnaces from the point of energy consumption, a largre number of measures to improve the efficiency of the reheating process have been intensively pursued especially in the periode after the first and second oil crises. Some of these measures are listed below with brief explanations.

1)Modification and improvement of operation

- ·Combustion control

  Low air ratio control by O_2 meter feedback system in combination with a feed foward control for sudden change of set temperature is applied.
- ·Optimization of furnace pressure
- ·Optimization of heat pattern in the furnace
- ·Lowering of charged steel temperature upon the extraction from the furnace
- ·Avoidance of size fluctuation of steel to be charged
- ·Lengthening the size of steel to be charged
- ·Optimization of space interval between each charge
- ·Improvement of furnace availability
- ·Lowering the furnace temperature for waiting period
- ·Optimization of heating-up speed
- ·Optimization of the number of operating furnaces to meet the productivity of rolling process

2)Modification of equipment and system

- ·Application of side wall burner system
- ·Extention of furnace length

  The longer the furnace, the lower the temperature of the flue gas at the outlet of the furnace and the recuperator, but the greater the expected heat loss from the furnace surface concurrently. Therefore, the effect of energy saving decreases successively with the furnace length, an optimal length existing in each case.
- ·Reinforcement of furnace insulation

  It is effective to reinforce the insulation of the top surface because the heat loss from it is as much as 70 % of the total. For example, 40 % of reduction in heat loss was reported when the top surface is covered with felt of 25 mm thickness, lowering the suface temperature from 160 °C to 111 °C.

·Reduction of furnace opening

The reduction of opening area and opening time remarkably contributes to energy saving. The charging door should always be closed except for the charging operation.

·Reinforcement of skid pipe insulation

The heat loss to the cooling water for skids is reduced by reinforcement of insulation for skid pipes. One effective method for this purpose is to insulate the skid pipes with double layers of ceramic fiber enclosed with castable.

·Modification of skid structure

An improvement is also realized by reducing the number or length of skids in case of walking beam furnace. According to an actual case, abcut 16 % of fuel saving was achieved by the modification of skid arrangement from rahmen to straight structure resulting in the skid number to 2/3.

·Application of dry skids

Cooling loss is zero if dry skids are applicable.
For example, 10 x10^3 kcal/t-steel of energy saving was reported by the modification of water-cooled skids to dry skids of heat-resisting steel casting.

·Reduction of skid mark

The skid mark is a factor affecting the optimum extraction temperature for the rolling process. Therefore, the reduction of skid mark can improve the energy consumption, lowering the extraction temperature. For example, a modification to semi-hot skids from conventional pusher type shows the lowering of extraction temperature by 15°C and the improvement of heat consumption by 4 x 10^3 kcal/t-steel because of the reduction of skid mark to the half.

·Jet preheating system

Preheating slabs by the high temperature flue gas contributes to energy saving. Such a preheating system pressurizing the hot gas from the recuperator and injecting it into the slabs has been developed and operated in Japan.

·Hot charge

·Hot direct rolling

3)Heat recovery

·High efficiency recuperator

Recently, the rectangular flow, channel type metalic tubular recuperator has been favorably used considering its compactness and easy maintenance.

However, high temperature oxidation and thermal stress for high temperature part and corrosion by SO_3 and accumulation of smud for low temperature side should be carefully taken into consideration.

·Evaporating cooling system for skid pipes

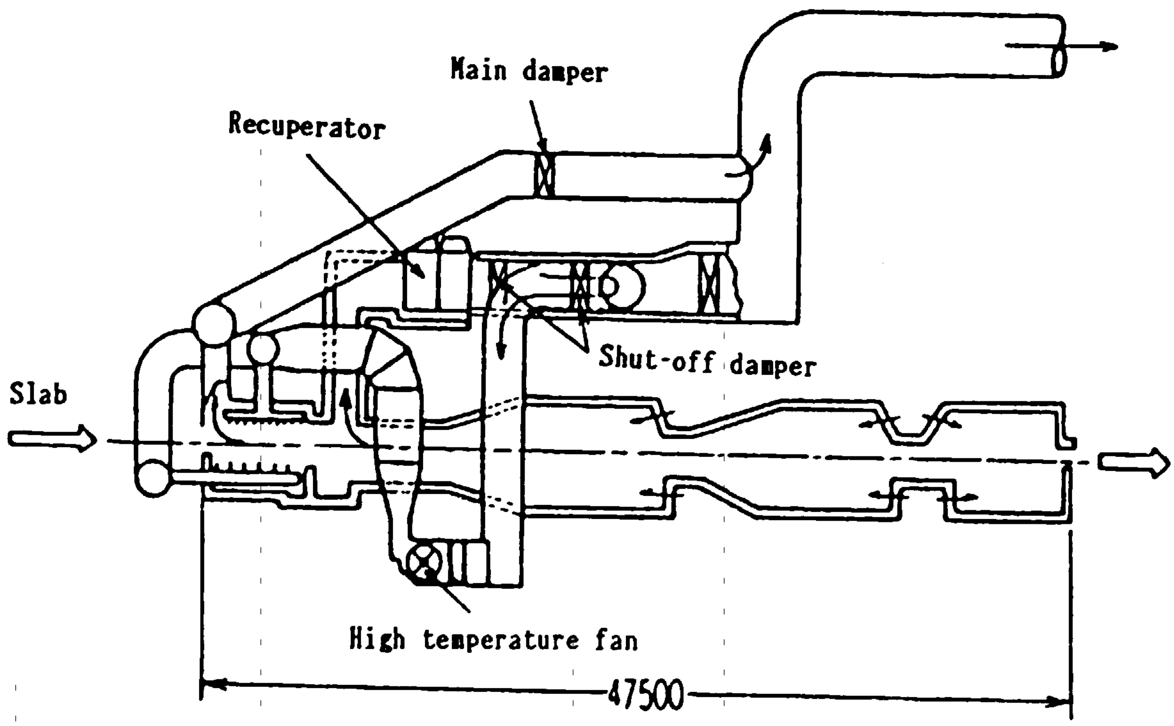
Skids are, in this case, cooled by the evaporation of hot water fed into skid pipes by recirculation pumps. The heat transferred to skids for cooling is recovered in the form of steam, which return to a drum and then flow into a common steam header.

(2)Energy saving effect

Energy saving measures which have been actually taken for reheating furnaces are different from plant to plant, but the average value of specific energy consumption for reheating furnaces in Japan is estimated at less than 300×10^3 kcal per 1 ton of steel.

(3)System flow chart

Flow diagram of jet preheating system is shown below.



An example of new type reheating furnace integrated with jet preheater

A12. Hot Direct Rolling(HDR) and Hot Direct Chargre(HDC)

(1)General description

One of the most effective energy saving methods in the rolling process is what is called hot direct rolling which supplies slabs and blooms from continuous casting machines directly to the rolling mills(HDR) or to reheating furnaces in the hot state(HDC). In order to put the HDR process into practice, it is indispensable to develop such technology as to produce non-defective slabs and blooms with sufficient productivity and temperature for rolling.

Because of no buffering part such as a reheating furnace, it is also indispensable to establish a total production control system by computer covering iron or steel making to end product manufacturing.

1)Continuous casting equipment for HDR

- Continuous operation of continuous casting is required for HDR to maintain the productivity of rolling process. In order to make continuous CC operation easier, ladle tarlets and large tandishes are mostly used.
- Continuous casting process is required to produce different size of slab and bloom so as to meet the requirement of the rolling process. For this purpose, the following two technologies have been developed.
  - Technology to change the width of mould during the continuous casting operation
  - Slab sizing mill to adjust the width and thickness of the CC slab in the hot state to send directly to the rolling mills
- Continupus casting process is required to produce hot, non-defective slab and bloom. For the non-defective production along with temperature control, the following measures are taken.
  - Higher density of roll distribution
  - Surface supporting of the cast just below the mould
  - Multiple reforming points
  - Slow cooling by air and water mixture injection
  - Minimization of heat loss, especially from the peripheral part of slabs
  - Removal of scales generated at gas-cutting using automatic descaler

2)Hot crack detector

- Optical crack detector
  - Reflection method for split crack
  - Radiation method for hair pin crack
- Thermal crack detector by induction heating
- Eddy current crack detector

3)Hot skirfer

Hot skirfer which skirfs only local part of detected cracks has been developed instead of conventional one.

4)Slab peripheral heater

This is provided ahead of hot strip mill or finishing mill, if necessary.

(2)Expected merit

Almost all the fuel consumed for reheating furnaces can be saved by the HDR system. The saving is expected of up to 300 x 10^3kcal/t-steel. On the other hand, the HDC is expected to save about 100 x 10^3 kcaal/t-steel.

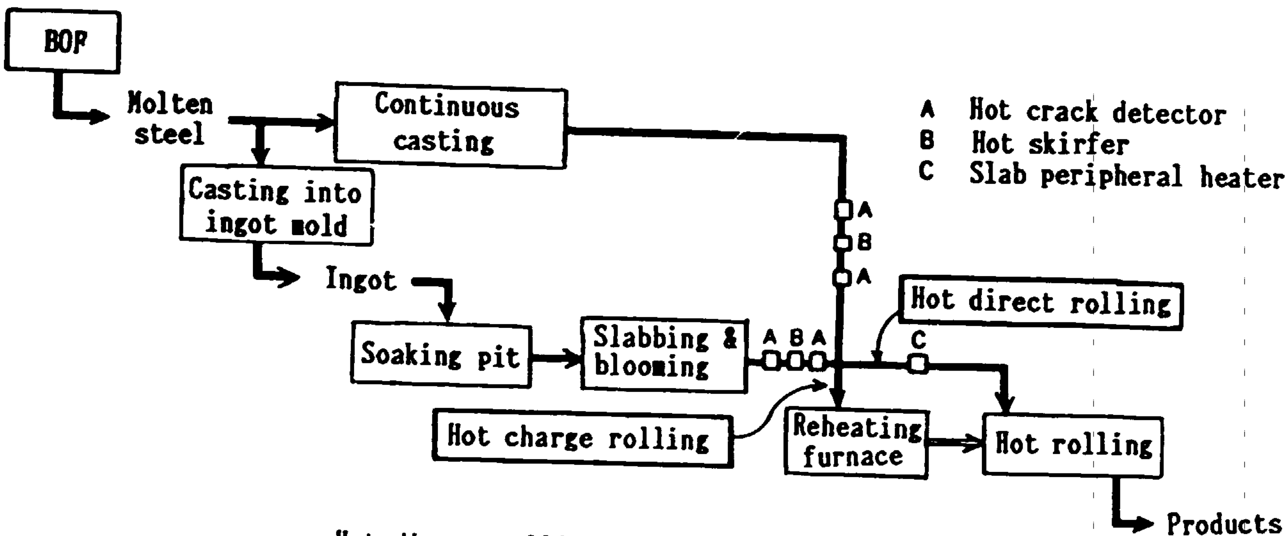
(3)Experience

HDR or HDC was introduced and experienced in almost all the integrated steel works in Japan, amounting to more than 20.

(4)Supplier

Sizing mill : Ishikawajima-harima Heavy Industries, ltd.
Descaler : Ube Kousan Corporation

(5)System flow chart



Hot direct rolling process flow diagram

B. Energy Saving in the Cement Industry

Energy saving in the cement industry has remarkably progressed through the introduction of a new suspension preheater, vertical mill and electricity generation by waste heat recovery. For example, the specific consumption of energy in Japan was reduced as much as 10.5 % from 114.3 l crude oil equivalence per ton of cement in 1972 to 102.3 in 1988.
The unit energy consumption in the case of the Japanese cement industry is shown below.

(1988)

Sector	Fuel l-HOE/t (%)	Electricity kwh/t (%)	Energy l-COE/t (%)
Raw material	0.2 (0.3)	29.2 (27.8)	7.8 (7.7)
Baking	71.1 (99.3)	28.4 (27.0)	81.9 (80.1)
Finishing	0.3 (0.4)	43.0 (42.6)	11.8 (11.5)
Others	0.0 (0.0)	2.7 (2.6)	0.7 (0.7)
Total	71.6 (100)	103.3 (100)	102.3 (100)

(Note) Source : Japanese Association of Cement Industry
HOE : Heavy Oil Equivqlence : 9,900 kcal/l
COE : Crude Oil Equivqlence : 9,400 kcal/l
Coal : 6,200 kcal/kg
Electricity : 2,450 kcal/kwh

According to the above table, 80 % of total energy is consumed in the baking sector. After the second oil shock, the fuel conversion from oil to coal was eagerly promoted in Japan and the coal proportion in total fuel consumption is nowadays almost 100 %.
The following systems have been introduced for further energy saving and are expecte
d
to expand in their application in the future.

(1) Raw material sector --- ·Vertical mill
·Modification of tube mill
(2) Baking sector --------- ·Low pressure loss type cyclones
·Speed control of induced draft fan(IDF)
(3) Finishing sector ------ ·Vertical mill
·Pre-grinding system
·Modification of tube mill

(4) Others ---------------- ·Power generation by waste heat recovery
·Mixed cement(ex.slag mixing)

B1. Vertical Type Roller Mill

(1)System description

The roller mill grinds cement and blast furnace slag into fine particles using three grinding rollers compacted on one rotating grinding table. The shape of roller tyres and table liners is in combination designed so as to ensure effective friction grinding as well as compressive grinding. Usually, the roller mill is equipped with a classification mechanism capable of adjusting the particle size distribution over a wide range. The particle size distribution of roller mills is equivalent to or better than that of conventional tube mills. The capacity range of roller mills is from 50 t/h(800 kw moter) to 350 t/h(5,500 kw motor) for cement.
Various grinding systems integrated with roller mills are possible. The following are examples of roller mill systems.

System 1 Bag filter
System 2 Bag filter and external material circulating
System 3 Bag filter and cyclone
System 4 Bag filter, cyclone and external material circulating

Roller mill systems are applied for both the raw material preparation process and the finishing process.

(2)Effect of roller mill

The roller mill requires less specific power consumption than that of conventional tube mills, resulting in a 35 - 40 % saving for cement clinker grinding, 45 - 50 % saving for slag grinding in overall power consumption. Some examples of the specific power consumption are shown below.

Raw material : Cement clinker		Roller mill	Tube mill
Blaine value		3,000 cm^2/g	3,000 cm^2/g
Specific power consumption	Mill	17-19 kwh/t-cement	30-34 kwh/t-cement
	Fan,Separater	5-7 kwh/t-cement	4-6 kwh/t-cement
	Total	22-26 kwh/t-cement	34-40 kwh/t-cement

Raw material:Blast furnace slag		Roller mill	Tube mill
Blaine value		4.000 cm^2/g	4,000 cm^2/g
Specific power consumption	Mill Fan,Separater Total	25-29 kwh/t-slag 6-8 kwh/t-slag 31-37 kwh/t-slag	50-60 kwh/t-slag 5-7 kwh/t-slag 55-67 kwh/t-slag

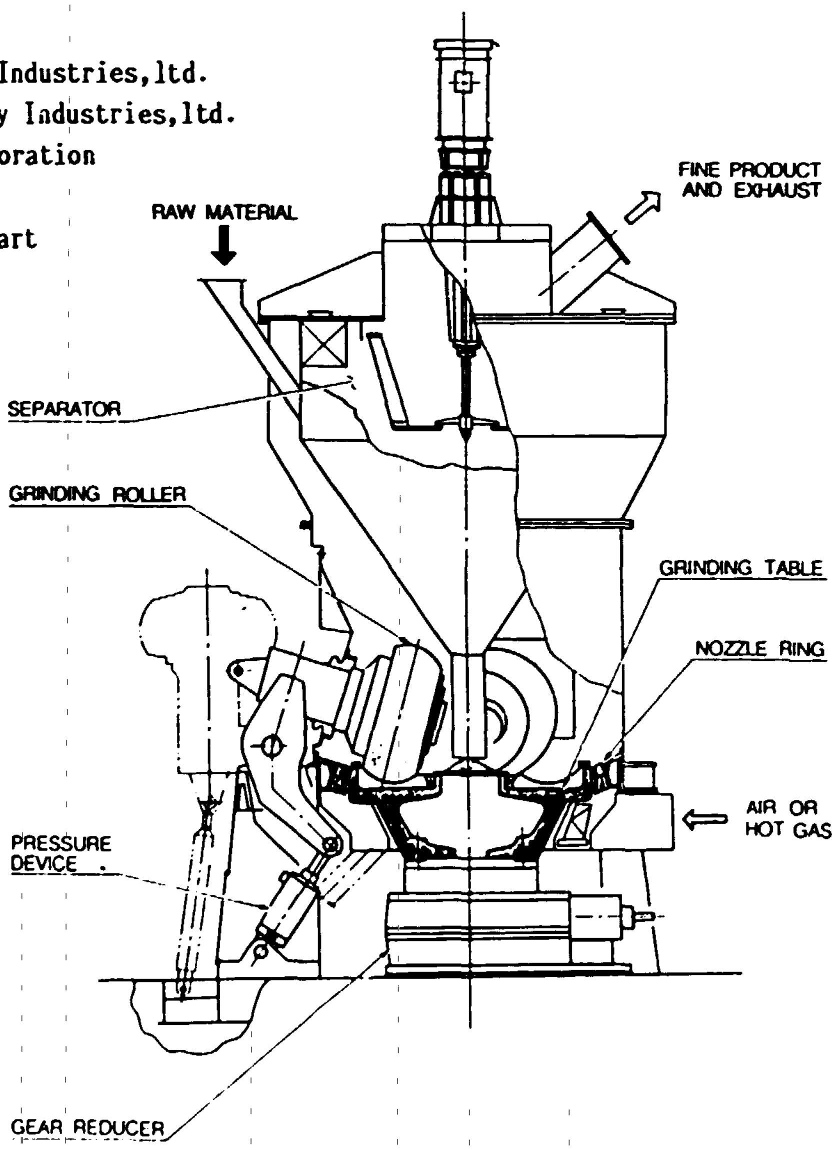
(3)Delivery record

More than 30 units of roller mills have been delivered to cement industries in Japan.

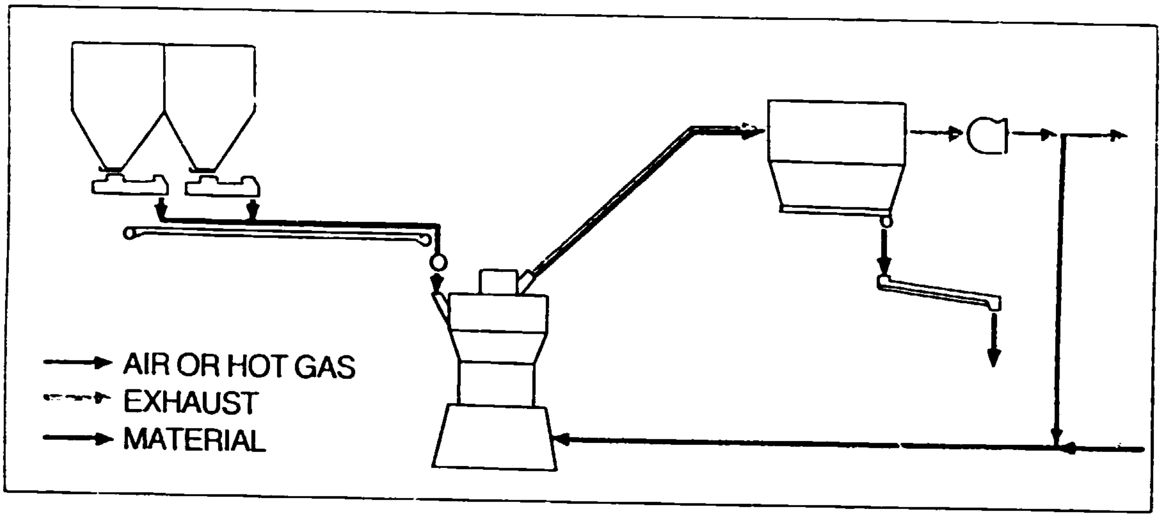
(3)Supplier

Kawasaki Heavy Industries,ltd.
Mitsubishi Heavy Industries,ltd.
Kobe Steel Corporation

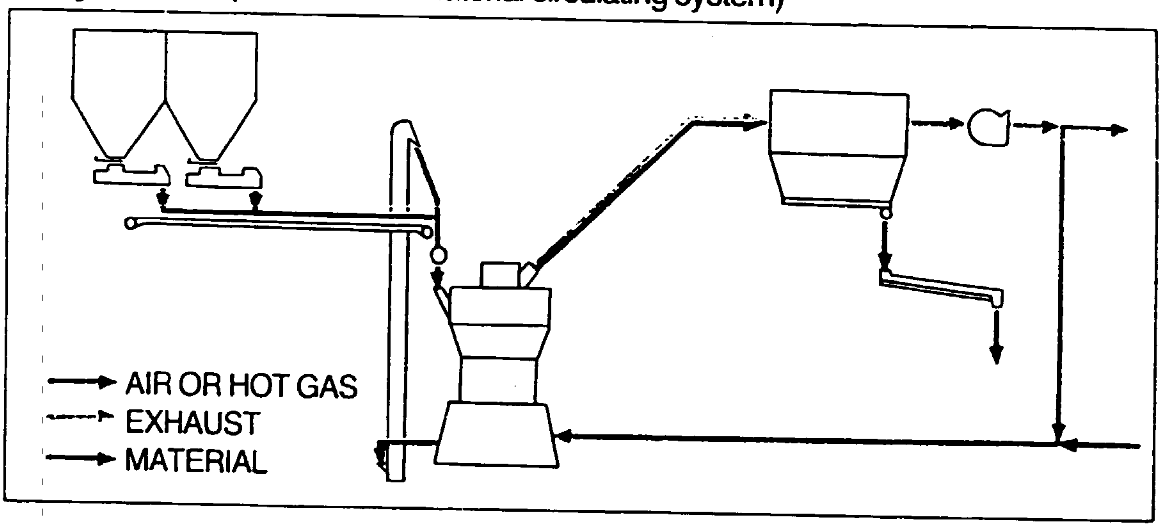
(3)System flow chart



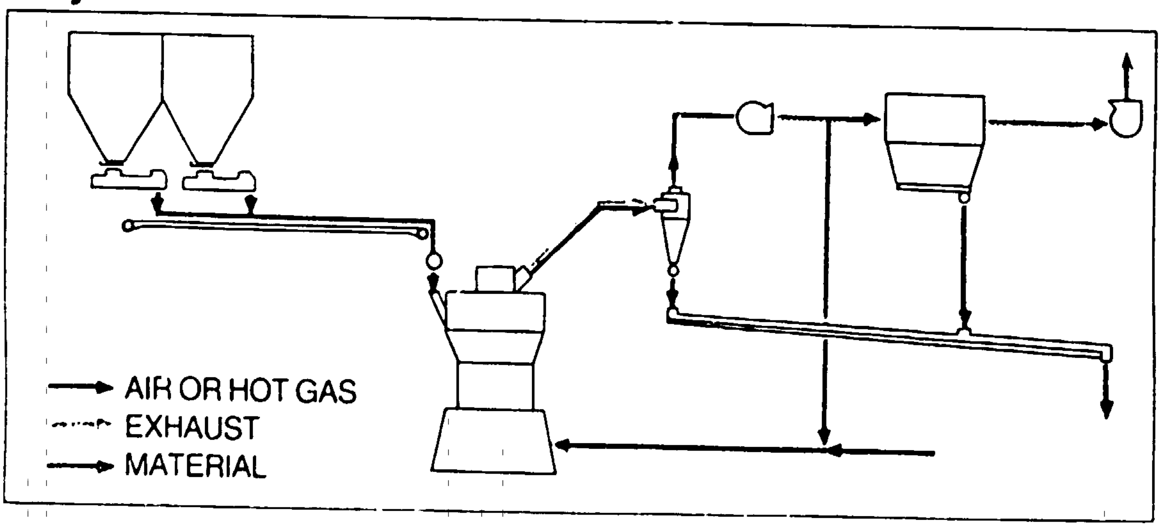
• **System 1**



• **System 2** (with external material circulating system)



• **System 3**



B2. Pre-grinding System

(1)System description

A remarkable improvement in grinding capacity and power saving can be achieved by introducing a pre-grinding system to existing tube mills. A vertical roller mill, which is specially designed for this purpose, produces fine particles more than approx. 30 % under 88 microns, and almost all of the product has internal cracks. Thus the grinding efficiency of the tube mill can be greatly improved. The compressive strength of the finished cement product is equivalent to or higher than that produced by the conventional tube mill.

Following system variation is available.

- System 1 : One pass pre-grinding, fed to tnbe mill or separator
- System 2 : Recirculating pre-grinding
- System 3 : Pre-grinding and drying

In the recirculating system, an amount of ground materials discharged from the pre-grinding mill(for instance, 30 %) are directly recirculated into the same mill without using a sreen separater. These recirculating materials function to increase the bulk density and compactness of the grinding bed on the table, thus ensuring the stable operation and improved the performance.

Typical combinations of pre-grinding roller mill and tube mill are shown in the following table.

Cement clinker			Cement raw material		
Capacity (t/h)	Roller mill (KW)	Tube mill (KW)	Capacity (t/h)	Roller mill (KW)	Tube mill (KW)
60	270	1,500	70	230	600
95	430	2,300	110	350	900
145	650	3,500	165	530	1,300
200	900	4,500	240	800	1,900
280	1,300	6,500	320	1,000	2,500
360	1,600	2 x 4,500	420	1,350	3,300

(2)Effect of pre-grinding system

Examples of the increase in grinding capacity and power saving are shown in the following table. The most effective capacity increase and power saving are obtained controlling the pre-grinding ratio at an optimum point for the existing tube mill.

Actual performance results of cement clinker and cement raw material

Material	Cement clinker		Cement raw material	
System	Pre-grinding system	Tube mill system	Pre-grinding system	Tube mill system
Capacity(t/h) increasing ratio(%)	170 41	121 -	360 80	200 -
Power consumption(kwh/t) Pre-grinding mill Tube mill Separator Others	 3.5 22.0 2.2 3.2	 - 31.0 3.0 4.1	 2.5 7.8 1.1 1.7	 - 14.0 2.0 3.0
Total Reduction ratio(%)	30.9 18.9	38.1 -	13.1 31.1	19.0 -

(3)Construction record

More than 10 systems are constructed in Japan.

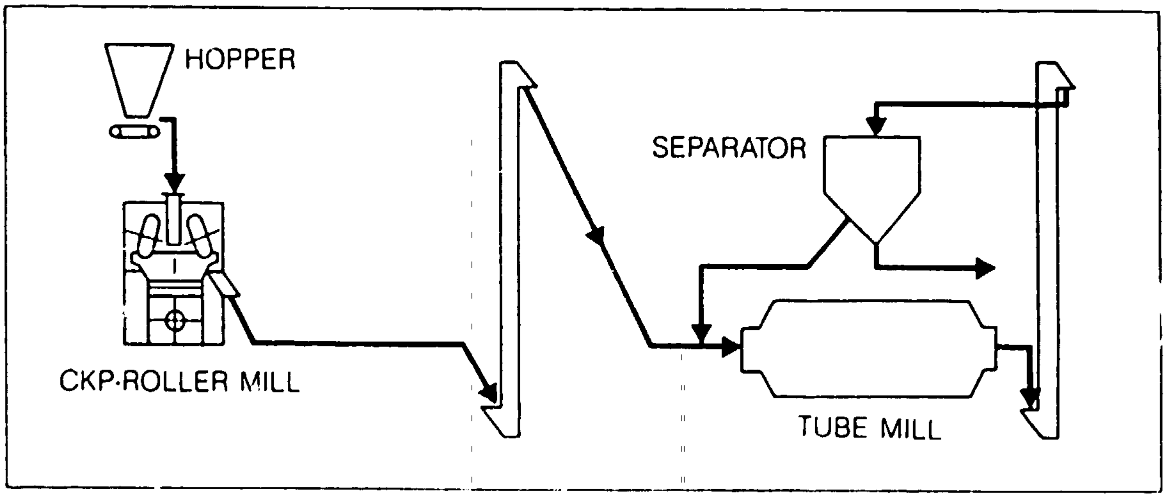
(4)Suplier

Kawasaki Heavy Industries,ltd.

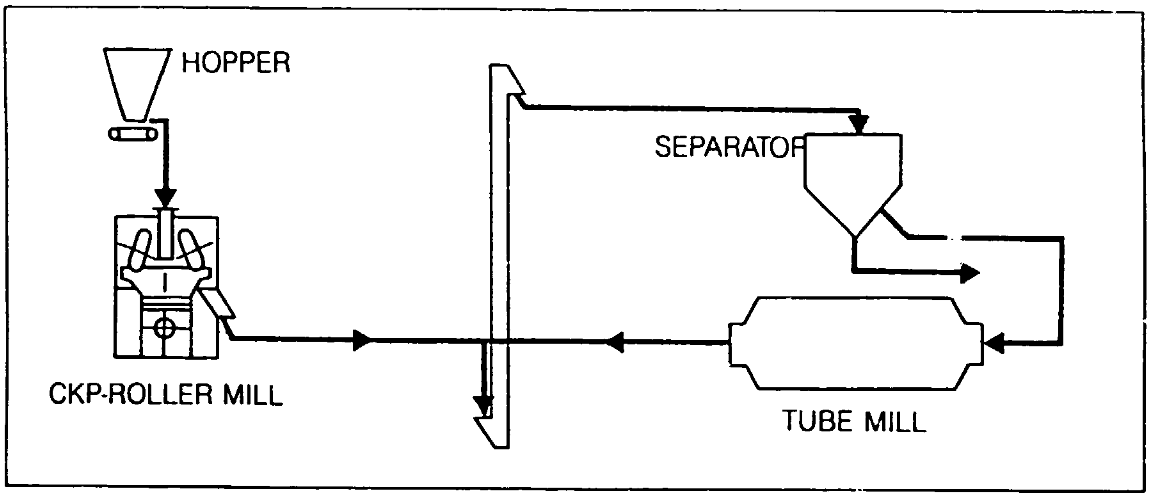
Nittetsu Kougyou Corporation

(5)System flow chart

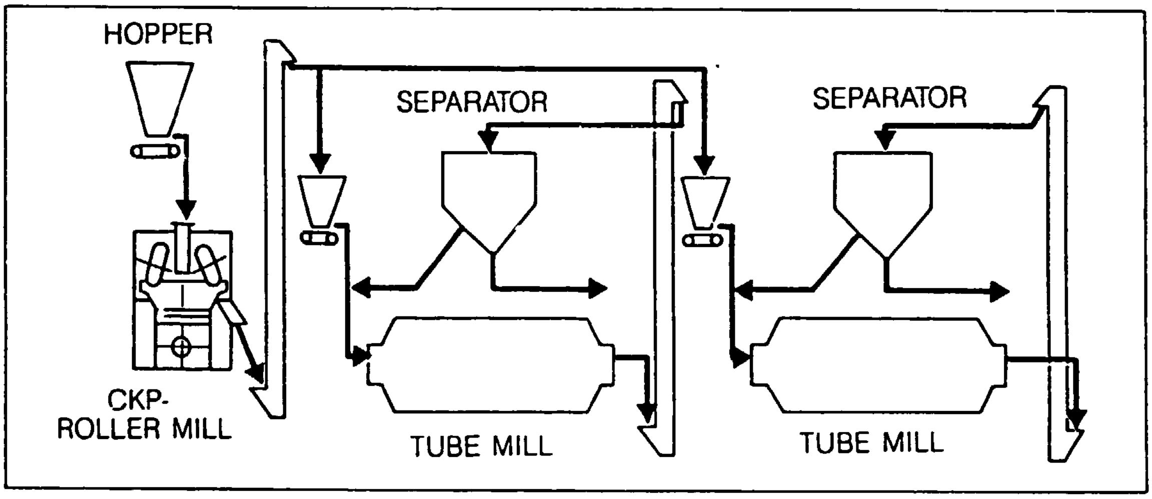
• System 1 (Fed to tube mill)



• System 2 (Fed to separator)



• System 3 (Fed to several mills)



C. Energy Saving in the Pulp and Paper Industry

The state of energy consumption in the pulp and paper industry in Japan is as follows.

		Electricity (kwh/t)	Steam (t/t)
Pulping process :	Ground pulp	1,320	0
	Refiner ground pulp	1,900	0
	Thermo-mechanical pulp	2,200	0.3
	Sulfite pulp (high yield N pulp)	1,100	2.6
	Kraft pulp (LBKP, continuous process)	370	3.7
	Chemi-ground pulp (Hot, Bleach)	700	1.6
	Chemical pulp	810	2.2
	Old paper pulp for plate	260	0
	for paper	430	0.4
Paper process :	News paper	525	1.9
	Printing paper	530-775	2.25-3.2
	Double side kraft paper	770-855	2.6-3.0
	White rolled paper	780	2.10
	Thin paper	1,580	4.05
	Tish paper	1,020	1.70
	Kraft liner	540	2.60
	White plates	395-420	2.55

The average specific energy consumption for paper and paper plate production in Japan is as follows. (1988, Source: Pulp and Paper Census, MITI)

Purchased heavy oil	0.195 kl/t	(Heat value: 9,700kcal/kl)
Purchased coal	0.091 t/t	(Heat value: 5,800kcal/kg)
Purchased fuel in total	0.253 kl-as heavy oil/t	
Purchased electricity	421 kwh/t	(Heat value: 2,250kcal/kwh)
Purchased energy	2.816×10^6 kcal/t	

The total energy consumption was reduced from $4,061 \times 10^6$ kcal/t in 1980 to $2,816 \times 10^6$ kcal/t by as much as 31 %. In this period, the use of coal was promoted and its share in total purchased fuel increased to 23 %. The house power genenation was also promoted so much as to produce 62.6 % of the total electricity consumption.
Main items of the energy saving system applied so far are the continuous pulping process, pulp washer of high performance and combined cycle.

C1. Plate Type Evaporator

(1)System description

Conventional tubular type evaporators are being replaced by new plate type evaporators. The plate type evaporator is primarily constituted from the body, heating elements, distributor and the entrainment separator. Heating steam is injected into the plate type heating elements which transfer the heat to the liquor flowing down on their suface.

The feed liquor is controled by the distributer to flow in a uniform pattern through the heating elements. The evaporated vapor passes through a wire mesh demister or a cyclone separator and then led to the next evaporator or condenser.

The great difference between the plate type and the conventional tubular type consists of the evaporating mechanism. The former applies the evaporation from the falling film into the free space, the latter applies the evaporation inside tubes filled with the liquor.

The advantages of the plate type over the conventional tubular type are as follows.

- Higher condensation degree

  The plate type can be operated under higher viscousity, which make it easy to obtain highly condensed liquor.

  In case of kraft pulp black liqour, more than 70 % of the solid concentration can be achieved by the plate type. On the other, the maximum concentration by the tubular type with forced recirculation is only 55 %.

- Low power consumption
- Scale is easily removed

  The scale is formrd on the outer surface of the plates and easily removed from the evaporator using a washing system. Scale observation windows are provided.

- Small hold-up of the liquor

  The quantity of the liquor held in the evaporator is only 1/10 of the conventional tubular type, resulting in the quick response to the load variation and start-up/shut-down.

- Compactness of the evaporating plant

  The evaporating plant incoporated with plate type evaporators can be designed much more compact and simpler than with the conventional tubular type. This means that the investment cost as well as the maintenance cost is lower.

Some variations of the evaporating system using the plate type are available. One of which is "Switching system" for multiple effect evaporator, and the other is "Vapor recompression system".

Switching system

For the heavy scaling zone such as the top evaporator in the multiple effect system, a three-section switching system as shown below has been adopted.

	State-1(4hr)	State-2(4hr)	State-3(4hr)
Step 1:Medium concentration(51→58%)	Section A	C	B
Step 2:High concentration(58→65%)	Section B	A	C
Step 3:Washing with dilute black liquor	Section C	B	A

Vapour Recompression system(VRC system)

The steam generated in the evaporator is compressed with a blower, and is used as a heating medium. This system eliminates the need for heating steam and cooling water.

Normally the operation is conducted at the vapour temperature of 100°C.

(2)Merit of the system

The general features of the plate type evaporator are mentioned above.

A comparison of the operationg cost among different systems is shown below.

Conditions :		
	Total evaporation capacity	30,000 kg/hr
	Feed liquor quantity	36,000 kg/hr
	Product liquor quantity	6,000 kg/hr

	3-effect system	7-effect system	VRC system
Heating steam(2kg/cm²g)	11,310 kg/hr	4,800 kg/hr	0
Cooling water(30 C)	360 t/hr	145 t/hr	0
Electricity for pumps	105 kwh/hr	120 kwr/hr	105 kwr/hr
Electricity for blowers	0	0	630 kwh/hr

According to the table shown above, the vapour recompression system is advantageous to the 7-effect system under such conditions that the price ratio of steam to electricity is larger than 125 kwh/t-steam.

(3)Construction record

More than 150 units(incl. more than 30 VRC system) ranging from 3 to 370 t/h of evaporating capacity were constructed in Japan.

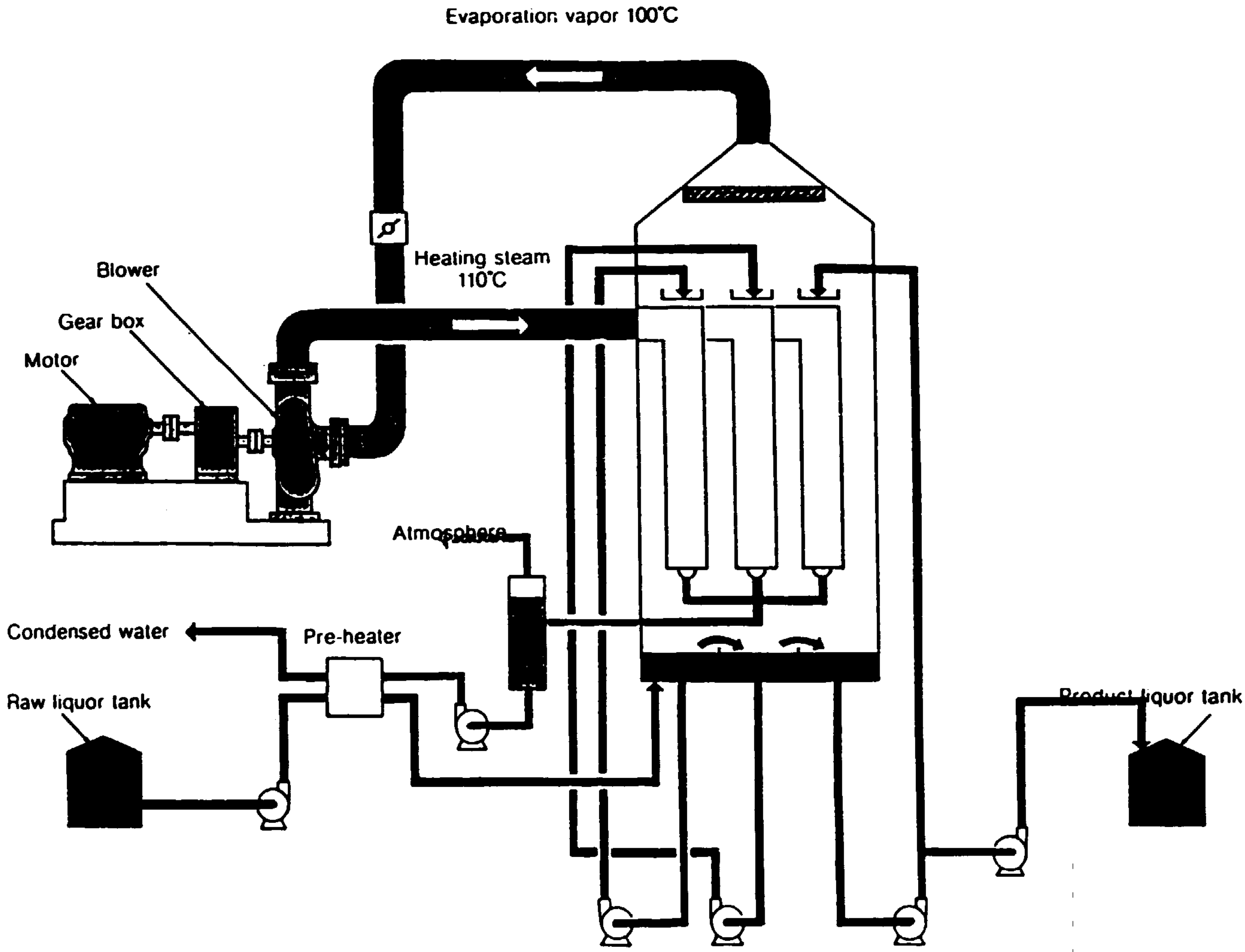
(4)Supplier

Sumitomo Heavy Indudtries,ltd.

Hitachi Zosen Corporation

(5)System flow chart

A flow diagram of VRC system is shown below.



C2. New Recausticizing Process with Pressurized Disk Filter(PDF)

(1)System description

The main part of the new recausticizing process consists of a thickener, a slaking tank, recausticizing reactors, a pressurized disc filter(PDF) for white liquor. The thickener used in this process has an internal reactor for the flock formation by polymer to ensure higher clarification by smaller equipment. The recausticizing reaction takes place in the three units of recausticizing reactor arranged in series. The retention time is 3 hours in total including the slaking tank. Each reactor is provided with an agitator of high flow type which prevents the mud particles from being destroyed and ensures the sufficent growth of particles. The power consumption is as small as half of the conventional paddle type agitator. The PDF is a kind of pre-coated filter. Filtering and dewatering take place in the liquid and gas phase respectively utilizing the pressure difference between inner and outer side of filter discs. A compressor is provided to generate this pressure difference.

The filtered cake is continuously scraped off from the discs by doctor blades. The clearness of the obtained filtrate is very high because of pre-coated type. The scaling such as that encountered in the vacuum filter is very little. The features of this system integrated with the PDF are summarized as follows.

- The required space is small.
- The yield of white liquor to green liquor is more than 95 %. This is 15 % higher than the 80 % expected in case of the conventional gravitational clarifier or tube filter. This higher yield results from such high solid concentration of lime mud over 75 %. For reference, it is only 35 to 40 % in the conventional system.
- The holding volume in the systsm is as small as 1/200 to 1/300 of the conventional case with gravitational clarifier. This small holding volume makes the start-up/shut-down operation and maintenance much easier.
- The alkali concentration in the green liquor can be increased due to the limited generation of weak liquor.
- The temperature of the white liquor can be kept high because of the compactness of PDF.
- The scaling troubles in the pulping process and evaporator are reduced due to the high clarity of white liquor.
- The quality of pulp is improved because of the perfect removal of impurities by the PDF.
- The temperature of green liquor can be lowered due to the larger heating-up in the slaker in connection with the reduced flow rate of green liquor.

(2)Merit of the system

A case study of direct saving by the new system with PDF is shown below in the form of differences from the conventional system.

Productiion scale : 1,000 ADT/day	Heat saved (10^3kcal/h)	Merits (Consumption reduction)	
Hot water to dilute the smelt	-950	Low pressure steam	-1.8t/h
Temperature-up of white liquor			
Heating steam for pulping	-476	Middle pressure steam	-1.00t/h
Activity-up of white liquor			
Heating steam for pulping	-102	Middle pressure steam	-0.22t/h
Evaporator steam	-334	Low pressure steam	-0.65t/h
Steam generation in recovery boilor	-590	High pressure steam	-0.74t/h
Heavy oil consumption in kiln	-196	Heavy oil	-21 l/h
Make-up of sodium sulfate	-	Sodium salfate	-9 kg/h
Purchased lime	-	Lime	-6 kg/h

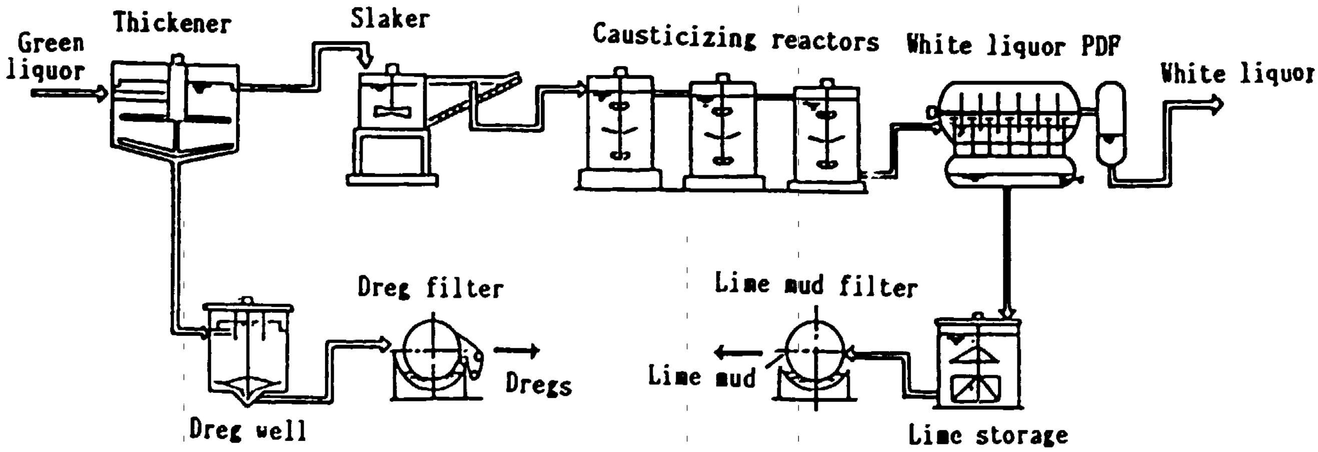
(3)Construction record

More than 15 units are in operation or under construction in the world.

(4)Supplier

Sumitomo Heavy Industries,ltd.

(5)System flow chart



C3. A Low-pressure-loss Cleaner

(1)System description

A large number of cleaners of water cyclone type have been used to remove impurities from the liquor before the paper machines as well as in the pulping process.
The newly developed cleaner is featured by its much reduced pressure loss compared with the conventional type. For example, the low pressure loss type requires only 50 to 60 percent of the energy necessary for the conventional type under the same flow rate.
This improvement was achieved mainly by the application of an inclined top plate on the head piece, and by the modification at the inlet nozzle.
Ceramic materials are used for anti-abrasive parts such as cone, bottom plate and reject nozzle.

(2)Merit of the system

A comparison of operation cost between the low pressure type and conventional type is given below. The total annual energy saving is obtained by muliplying the annual operationg hours, unit price of electricity and the number of cleaners used in the plant.

Cleaner type	Low-pressure-loss type	Conventional type	Difference
Flow rate	2.0 m^3/min	2.0 m^3/min	-
Pressure loss	2.8 kg/cm^2	1.6 kg/cm^2	1.2 kg/cm^2
Power consumption	13.0 kw	7.5 kw	5.5 kw

(Note : The pump efficiency is assumed as 70 %)

(3)Experience

Thousand of low-pressure-type cleaners have been manufactured and are in operation in Japan.

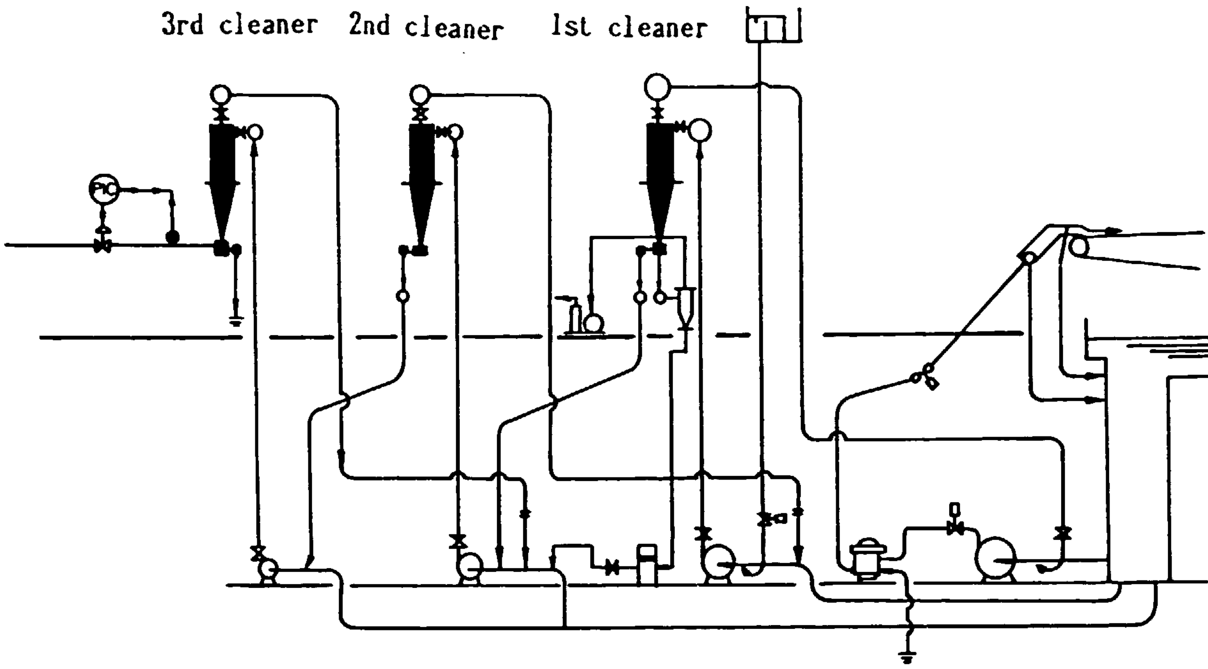
(4)Supplier

Asano Eleco Corporation

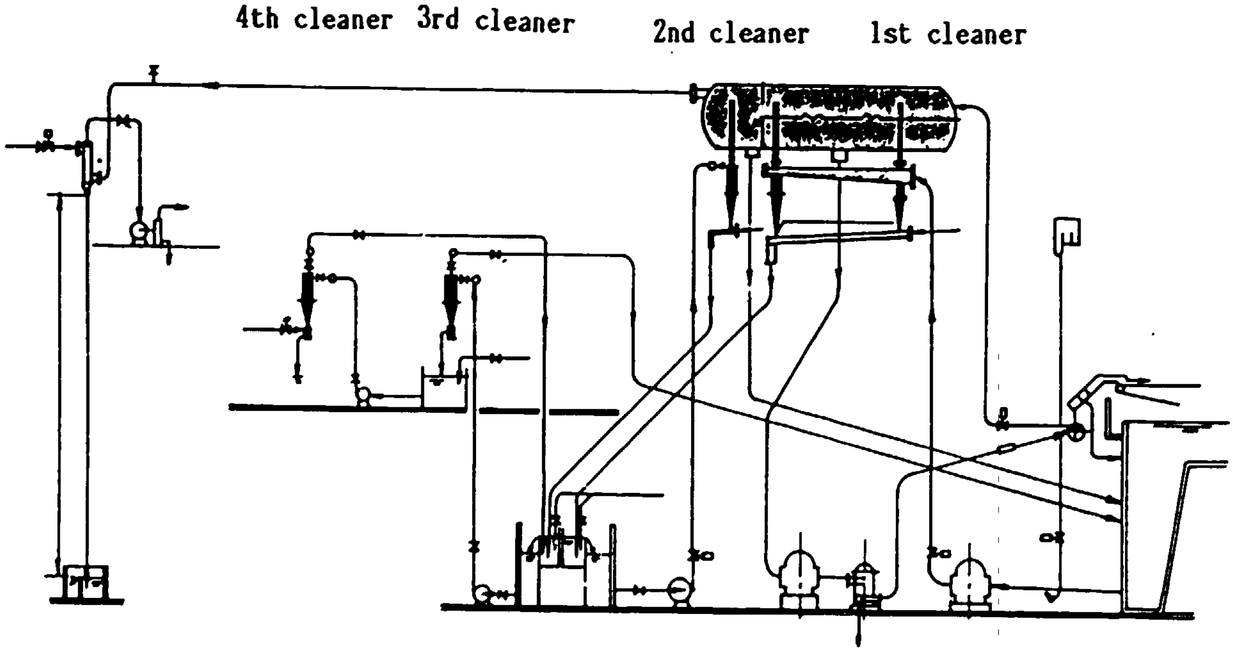
(5)System flow chart

Several cleaning systems incorporating the low pressure type cleaners are described in the following page.

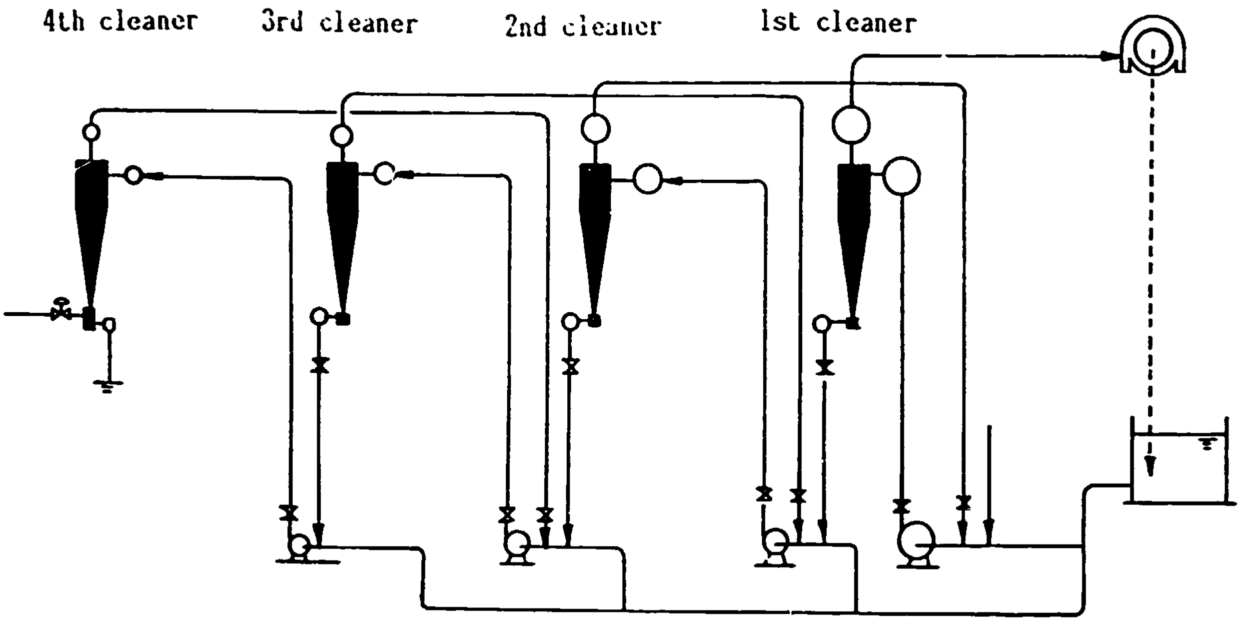
Exsample of cleaner arrangement ahead of paper machine with vacuum rejecting



Exsample of cleaner arrangement ahead of paper machine with deairator

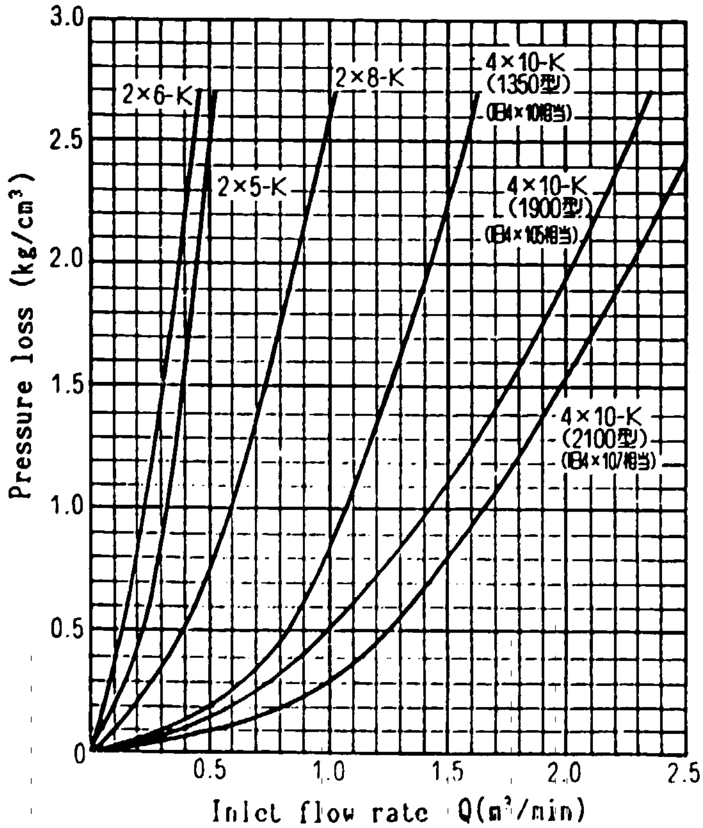


Exsample of cleaner arrangement for pulping process



Characteristic curve of typical cleaner of low pressure type

Each curve represents a definite model respectively.



C4. Totally Enclosed Drying System

(1)System description

The paper machine is usually enclosed with a hood system and ventilated to control the atompospheric conditions for paper processing so as to prevent the condensation of vapour inside the hood. The energy consumption of the hood system is, therefore, affected by the operating dew point, which decides the relationship of volume and temperature of the air to be ventilated. The higher the temperature of the ventilating air, the smaller the air volume to remove a definite amount of vapour generating from the paper process. This relationship is not proportional but the volume is strongly reduced by a small increase of the temperature. That is to say, the small quantity of ventilating air at a higher temperature takes a great advantage to the large quantity at lower temperature In order to reduce the volume of ventilating air, it is necessary to contain the papaer machine in an air-tight enclosure and to feed and suck only a limited amount of heated air. Thus, the totally enclosed ventilating system reduces the consumption of steam used for vaporizing the water from the paper.

This system consists of the closed hood and enclosure, forced and induced draft fans, ducts, filter, mist eliminater and air heating system.

An amount of air taken from the air intake passes a filter and is then heated up by economizer and steam heater, and sent to each feeding point by means of forced draft fan and distributing ducts. The air injected inside the enclosure vaporizes the water in the paper and then, together with the vapor, is sucked into the discharging ducts by the induced draft fan. This mixture of air and vapour is then used to pre-heat the fresh air at the economizer, and further to produce an amount of hot water if required, and is then discharged from a stack after mist-elimination. The cealing of each opening is very important in this system.

The totally enclosed drying system can be operated at the dew point of 65°C, which is much higher than 40 to 45°C in case of the open hood system, and 58 to 60°C in case of conventional enclosure system.

(2)Merit of the system

The energy saving ability of the paper machine can be greatly improved by this system. For instance, it is expected that the steam consumption of 2.5 t/t-paper by the conventional system is reduced to 1.8 to 2.0 t/t-paper by this system. In addition, this system enables an increase in the operating speed of the paper machine by suppressing the fluttering of paper.

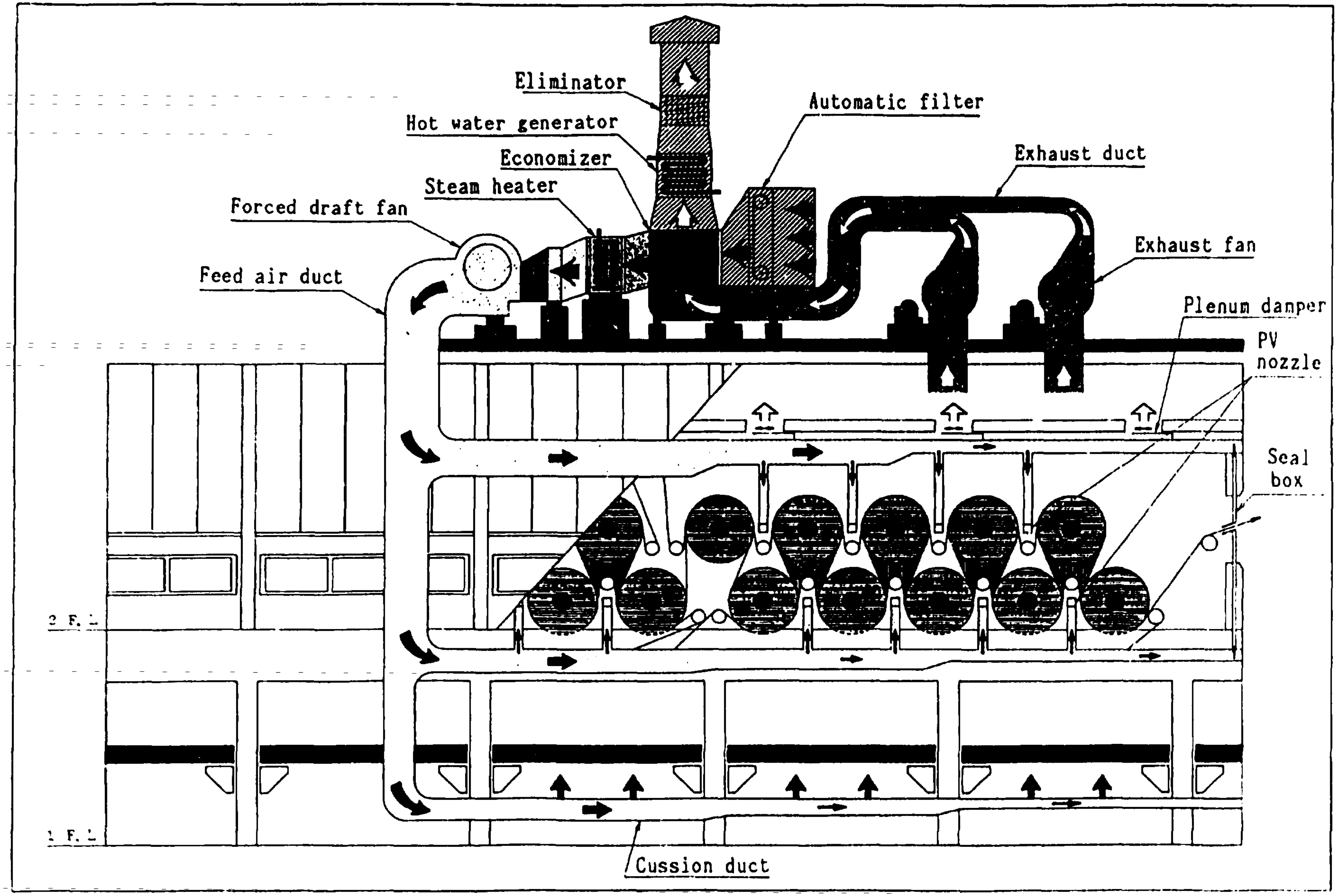
(3)Construction record

More than 15 units have been constructed in Japan.

(4)Supplier

Shiratori Engineering Co.,ltd

Totally enclosed drying system



C5. Sludge Drying and Incinerating System

(1)System description

Pulping plants generate a large amount of sludge from the pulping and water teatment processes. The incineration such pulping and activated sludge is very difficult because its heat value is near the self-burning limit because of high water content.

Two methods are available for the incineration of the low heat value, wet sludge without any supplimentary fuel. One is the fluidized bed combustion, the other is the cyclone combustion. In both cases, the drying system of raw sludge plays an extremely important role.

The sludge dryer used in this system is called milling dryer, furnished with a couple of high speed crushing runners at the bottom. This crusher induces the high temperature drying gas and mixes it with crushed materials instantaneously to vaporize and fluidize them.

The total system consists of cyclone or fluidized bed incinerator, milling dryer, dust cyclone, paddle mixier, wet scrbber, sludge storage bin with constant feeder, conveyors, ducts and fans.

The raw sludge, conveyed from the storage bin to the paddle mixer, is mixed with an amount of dried product to decrease the appearance water content. The dried particles from the dryer are captured by the dust cyclone and then sent to the incinerater excluding an amount to be sent to the paddle mixer for recycling. Neumatic conveyor is used for the feeding of dried product to the burner mounted on the upper part of incinerator. A regulated quantity of combustionon air is fed to the incinerator from its middle and lower part. Burnt ash is extracted from the furnace and storaged in the ash bin after adjusting moisture. The hot gas from the furnace goes into the waste heat boilor for the heat recovery if surplus heat is available. Fine dusts in the flue gas from the dryer are removed by the wet scruber.

The features of this system are summerized below.

- Stable and instantaneous drying excludes clogging and odor problems.
- Required space is small because of vertical type designing.
- Operational cost is low because of the integrated effect of high cumbustion efficiency, low heat loss from the surface and short drying time.

(2)Merit of the system

The relationship of heat recovery and the raw sludge quality is shown in the next page. The operational cost is expected to be 2/3 of that for conventional rotary kiln system.

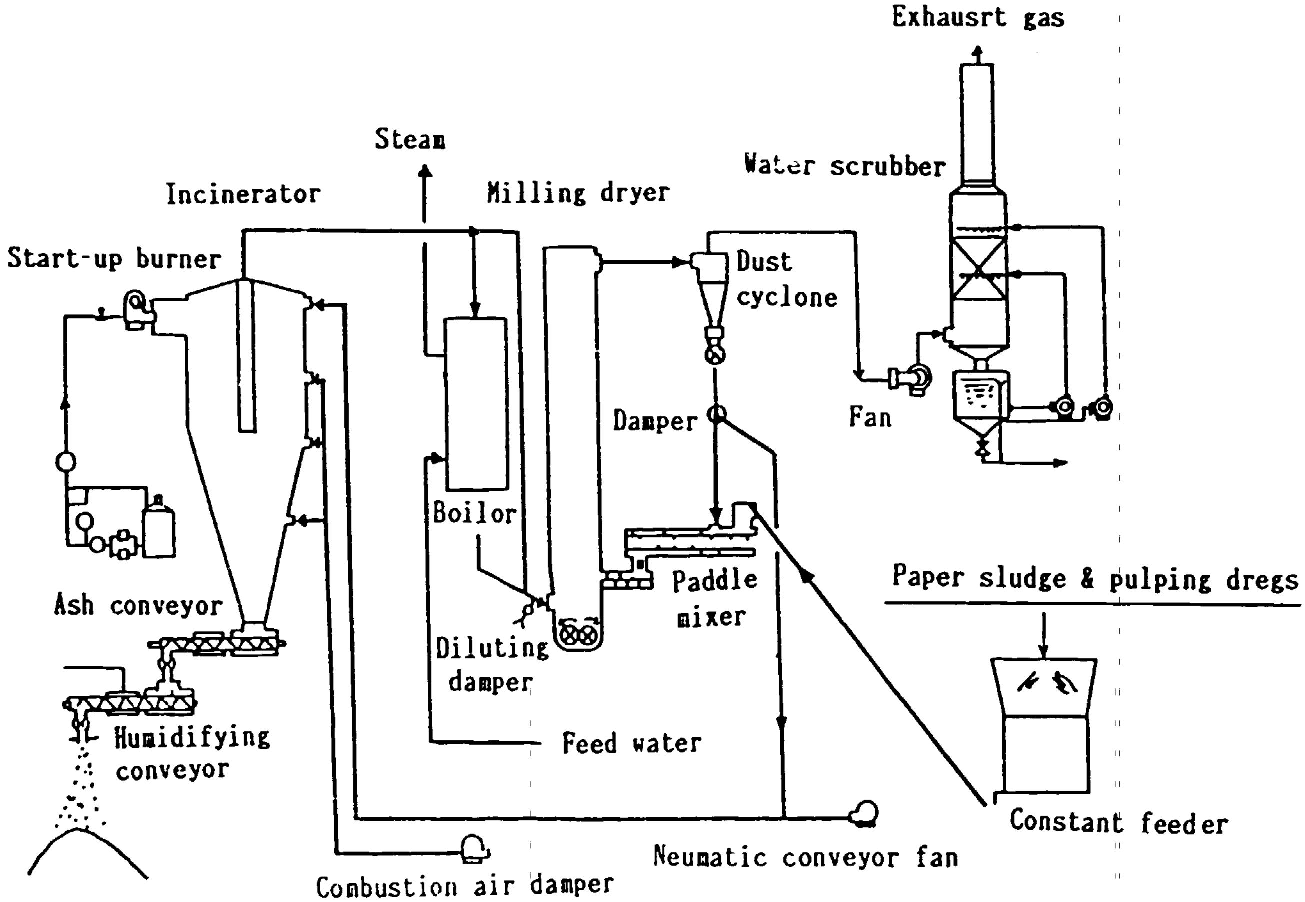
(3)Construction record

More than 50 plants by this system have been constructed in Japan and Korea.

(4)Supplier

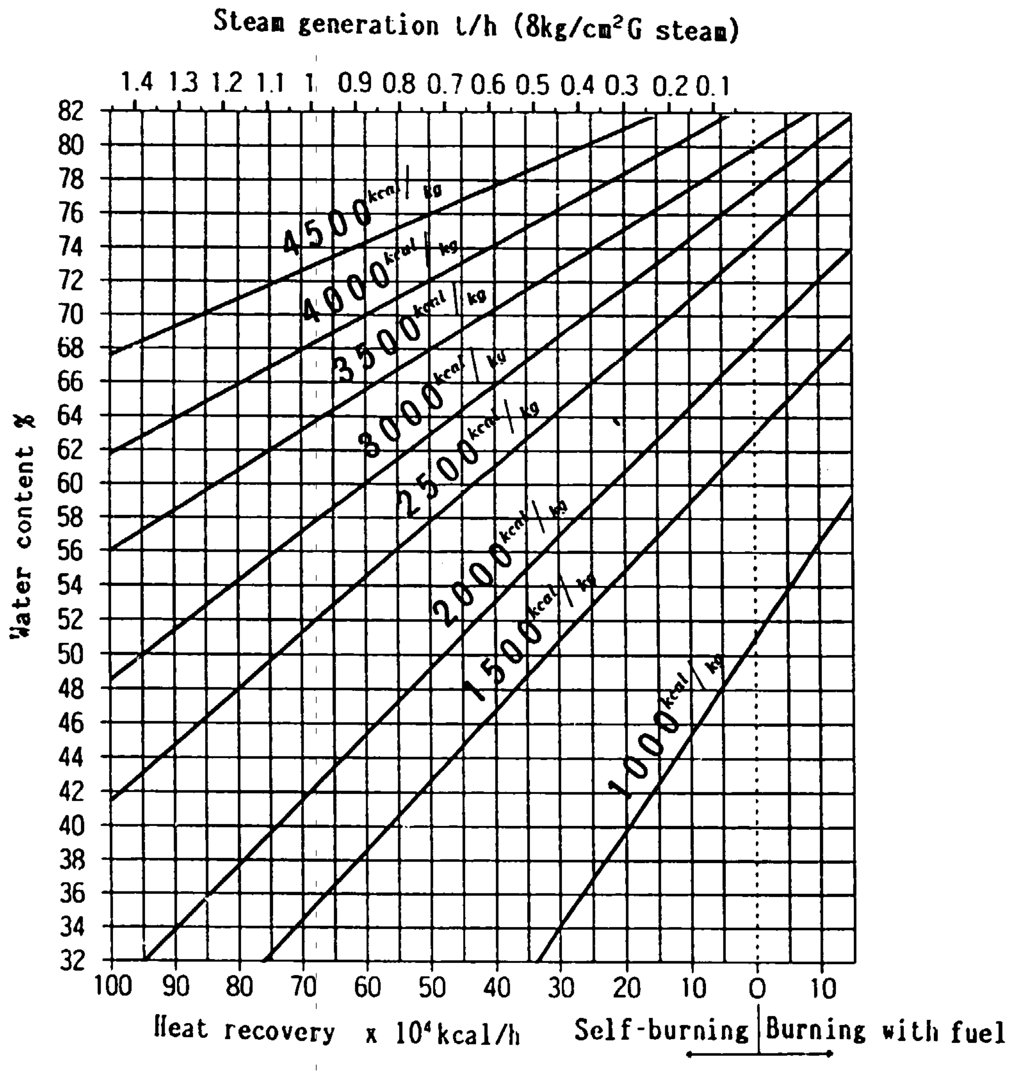
Ryowa Kakoki Co, ltd.

(5)System flow chart



Paper sludge incinerating system with milling dryer

Heat recovery from 1,000 kg/h of sludge



C6. Co-generation system

(1)System description

The co-generation system, which produces both electricity and steam by recovering the waste heat from the gen-set, has a great advantage for the steam using industry such as pulp and paper manufacturing.
According to the type of engine, the co-generation system is classified into the following three.

	Diesel Engine	Gas engine	Gas turbine
·Fuel	Diesel oil	Natural gas	Natural gas,LPG,Oil
·Thermal eff. of engine	35 - 43 %	30 - 36 %	22 - 30 %
·Heat recovery	30 - 40 % Hot water (Steam:up to 20%)	35 - 45 % Hot water (Steam:up to 30%)	45 - 55 % Steam
·Total heat recovery	70 - 85 %	70 - 80 %	70 - 80 %
·Heat/electricity ratio	1.0 - 1.5	1.5 - 2.0	2.5 - 3.0

From the view point of waste heat recovery by steam generation, the gas turbine system is preferable for the pulp and paper industry. Besides, the gas turbine co-generation system has the following advantages over the other systems.

- Flexibility in fuel selection
- Cooling water is not necessarily required
- Small vibration and noize generation, resulting in small foundation and simple enclosure
- Small Nox emission and easy Nox control by water or steam injection
- Easy maintenance

The gas turbine co-generation system consists of a turbine-generater unit with govener controler and automatic synchronizing device for the paralell operation with the commercial electricity net works, waste heat recovery boiler with economizer, starting system and fuel supply system such as gas compressor in case of gas fuel.
A duct burner can be easily installed between the turbine and the boiler in order to increase the steam generation, if necessary.
By-pass ducts and damper for the waste heat boiler have been provided in order to adjust the steam generation to the demand value. Recently, the system without by-pass duct, and with excess steam discharging equipment instead, is increasing.

(2)Merit of the system

The merit of the co-generation system is affected by a lot of factors such as total heat recovery rate, price of fuel and electricity, availability and average load factor of the system, possibility to sell excess electricity and so on. In case of preferable conditions, the simple pay-back (=Investment/annual operational cost) is only 2 years. In Japan, the gas turbine co-generation system is introduced to pulp and paper companies mostly with the pay-back of 2 to 4 years.

(3)Application record

The co-generation systems introduced to the pulp and paper industry in Japan up to 1990 is as follows.

Gas turbine system	8 units	(500 - 7,600 kw)
Diesel engine system	30 units	(150 - 7,000 kw)

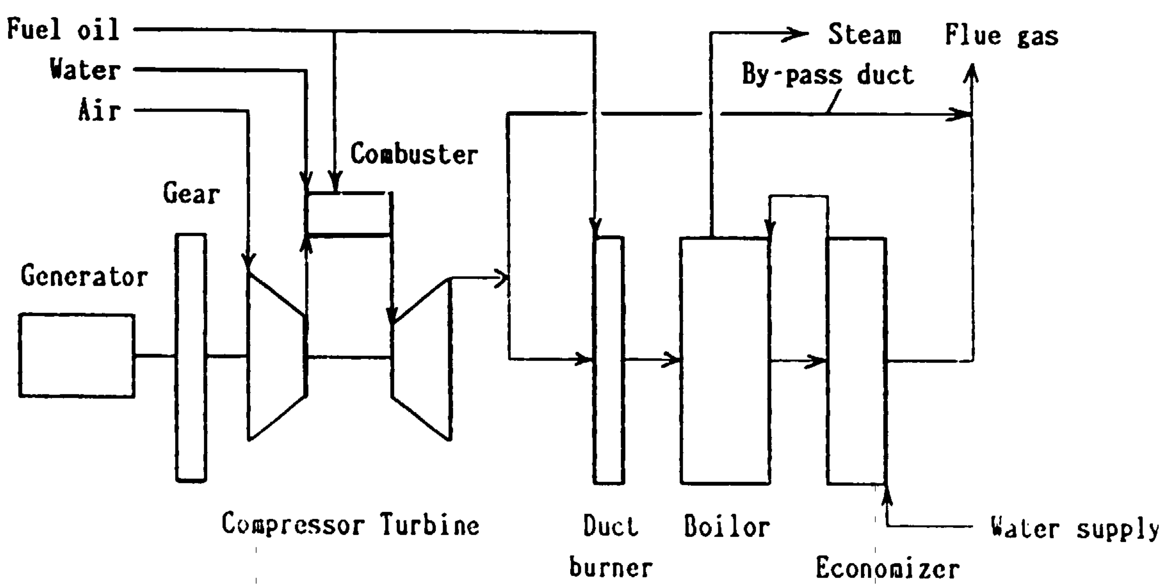
The share of gas turbine system is expected to increase in the future.

(4)Supplier(Gas turbine system)

Kawasaki Heavy Industries,ltd
Mitsui Zosen Corporation
Niigata Machinery
Kobe Steel Corporation

(5)System flow chart

Gas turbine co-generation system with duct burner and by-pass duct is shown below.



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