Item	Vertical roller mill for raw materials	Application process: Raw material process

Background

Grinding raw materials needs lots of energy. Tube mills had been used for grinding, but the energy efficiency level was lower. Therefore, the introduction of highly efficient grinding equipment was anticipated.

Descriptions

The vertical roller mill has high energy efficiency and the installation space is smaller compared with tube mills. These days, the vertical roller mills have been widely adopted.

A） Structure

(1) The rollers are hydraulically pressed against a disc table and the feed is ground between the rollers and the disc table.
(2) The classifier is housed above the rollers.

B） Feature

(1) The power consumption level for grinding is lower than that of tube (ball) mill.
(2) The remaining time of raw materials in this type of mill is much shorter than that in tube (ball) mill; therefore, the crushing process and mixing process became more harmonized and this contributes to quality control.
(3) The installation space is smaller and this leads to lower noise level.
(4) This type of mill can crush materials which are too large to be fed into the tube (ball) mill.
(5) Ground materials are dried by the flue gas from the kiln.

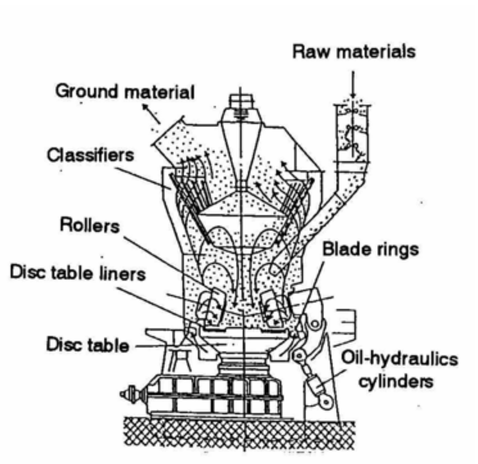


Fig.1 Vertical roller mill

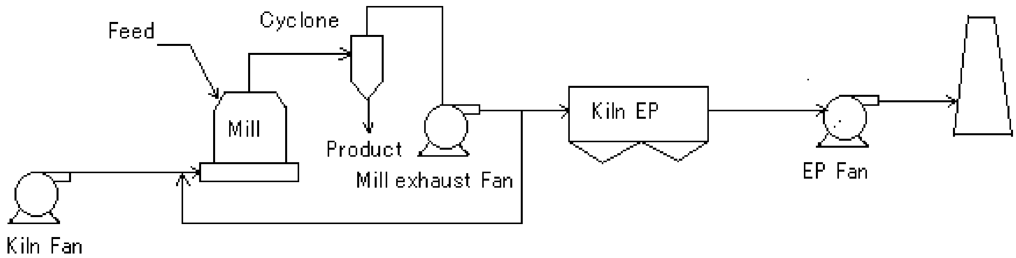


Fig.2 Schematic process flow of vertical roller mill for grinding of raw materials

Vertical roller mills are adopted in 20 cement plants (44 mills) in Japan.

Results

Table Energy saving effect of the vertical roller mill

		Ball mill	Vertical roller mill	Effect(%)
Production	%	１００	160～180	60～80(increase)
Specific power consumption	kWh/t-RM	20～26	14～18	About 30 (Reduction)
The reduction of power consumption(*)	kWh/y			2,240,000

Cost estimation

About 14million US$ [Newly-built] and about 230 million US$ [retrofitted], including the cost of supplemental facilities [200t-RM/h] [1US$=¥110]

Related matters

References

Item	External circulating system to vertical roller mill	Application process: Raw material process

Background

In the vertical roller mill which is widely used in the raw material grinding process, raw materials input grinding table are crushed and pulverized on it and transported to separator by kiln exit gas introduced into the mill as drying, transporting and separating purpose. In case that the proposed external circulating system is not installed, which is called conventional system, uncrushed and/or half crushed large size materials undergone rotating and grinding works on the table and jump out from it have to be kept above the table or transported to separator by the gas blown around the table to hold them in the mill inside until desired particle size by clinkering process is gotten. This internal material holding and separating works by the gas requires huge energy. It amounts about 60% of this raw material grinding process. Around 1980, it is proposed the external material circulating system that uncrushed large size raw materials jumped out from the table is re-transported by mechanical system in order to reduce gas blow and transportation energy.

Descriptions

In case that the proposed external circulating system is provided to the vertical mill, the uncrushed materials jumped out from the table fall through gas inlet box to and collected by the mechanical transportation equipment installed below the mill such as chain conveyor and bucket elevator etc. And then they are re-transported to fresh material feed equipment to re-send the mill. Since the uncrushed raw materials are not blown-up by the gas, transportation energy of the gas, which is generated by mill fan, extremely decreases.

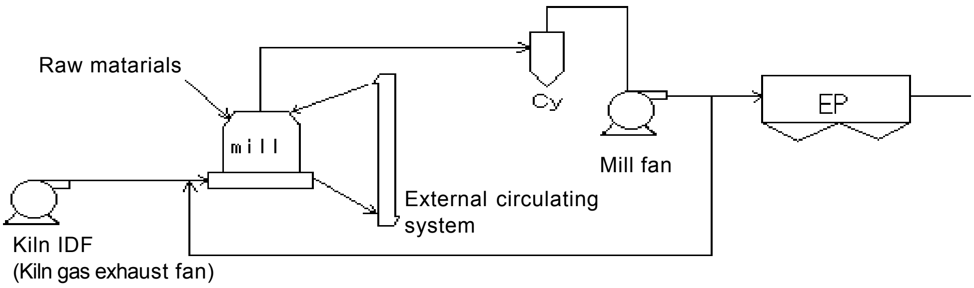


Fig. Flow chart of roller mill adopting the external circulating system.

Results

As compared with conventional internal circulating system, power consumed for fan is reduced until half and it's possible to reduce power of grinding system by about 30%

Table The comparison of external circulating system

		Conventional system	External circulating system	Effect
Capacity	t/h	490	496	
Gas pressure loss (draft)	mmAq	1,110	770	30% (Reduction)
Gas flow rate	m^3/min	15,400	12,000	22% (Reduction)
Total electrical power consumption	kWh/t	19.4	13.5	30% (Reduction)
Mill and Separator		8.9	7.7	
Mill Fan		10.5	5.7	50% (Reduction)

Cost estimation

It depends on scale of facilities. For example, about 820,000 US$ per unit.
[1US$=¥110]

Related matters

Reference

Item	Direct dust collection system to vertical mill grinding process	Application process: Raw material process
Background	At the beginning stage when vertical roller mill was adopted to cement manufacturing, mill gas circulation fan and dust collection fan are required and their power consumption was larger.	
Descriptions	The conventional process gas flow of the mill grinding system generally consists of vertical roller mill with separator, cyclone, mill circulation fan, and electrostatic precipitator (EP) and EP fan as shown in Fig.1. Pulverized final products, which is called kiln feed raw meal, are collected at the cyclone and EP. Because of large pressure loss at the cyclone and in order to control mill gas flow, mill circulation fan and EP fan are provided after the cyclone and EP respectively. Power consumption of these two fans reaches about 10kwh/t-raw-material. In the direct dust collection system shown in Fig.2, process flow is simple. The raw materials are dried and ground by the mill simultaneously in one-pass kiln exit gas and then fine product after separation is sent to EP directly. Since the cyclone is not installed, system pressure loss reduces. And as the mill fan treats de-dusted gas only, its power consumption largely decreases. As of 2002, this system is used at four plants in Japan.	
Results	Power consumption of fan(s) reduces about 3 to4 kWh/t.	
Cost estimation	When a mill with a production capacity of 420 t/h was newly constructed, the total cost was about 25 million US$. [1US$=¥110]	
Related matters		
Reference		

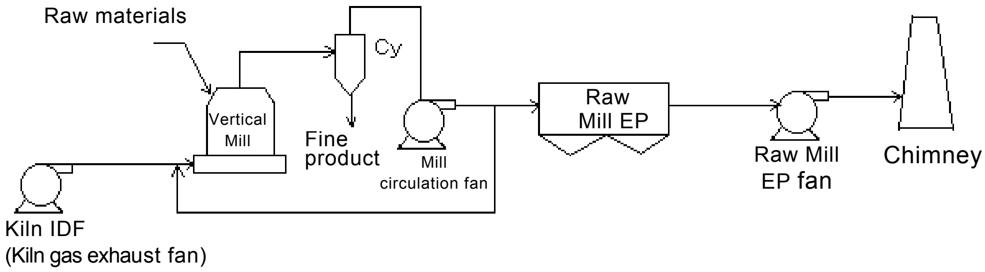


Fig.1 Flow of Conventional Vertical Mill Grinding System

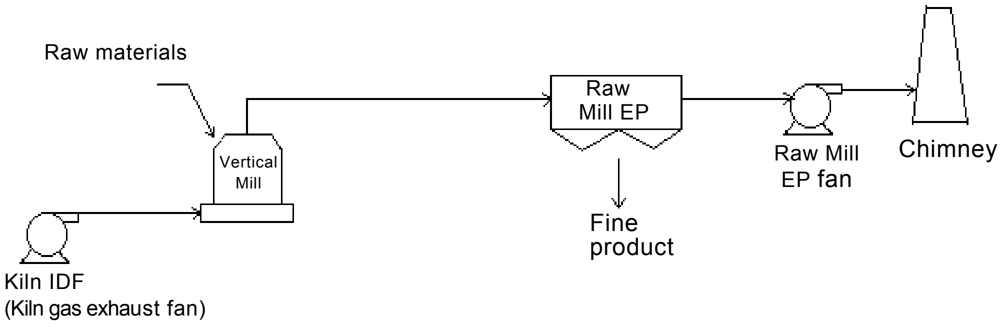


Fig.2 Flow of direct dust collection system

Item	Pre-grinding equipment for raw material grinding process	Application process: **Raw material process**

Background

Recently, the vertical roller mill having great grinding performance is widely applied to the raw material grinding process. However, tube mill, which has about 30% poor grinding performance as power consumption, has been still used many existing cement plant. The improvement of this tube mill grinding system is highly expected.

Descriptions

The tube mill comminutes raw materials by impact and friction between grinding balls, which hit raw materials as well as between grinding ball and mill lining. Many of this type mills have two grinding chambers for coarse and fine grinding. Grinding ball size and their distribution are designed and adjusted considering raw material conditions and mill dimensions etc. However, the energy efficiency in the coarse grinding chamber is extremely poor and there is limitation to improve both performances for coarse and fine grinding on the same mill by ball size selection etc.

Therefore, a new system was proposed and developed by installing a pre-grinder, which is roller mill or roller press, as coarse grinding before the existing tube mill, which is exclusively used for fine grinding. This system greatly reduced the specific power consumption and improved the production capacity. This system is now installed at three plants in Japan and improvement of production of 50 to 100% has been achieved when roll mill type pre-grinder is used.

As the pre-grinder, vertical roller mill is often used considering its great grinding efficiency.

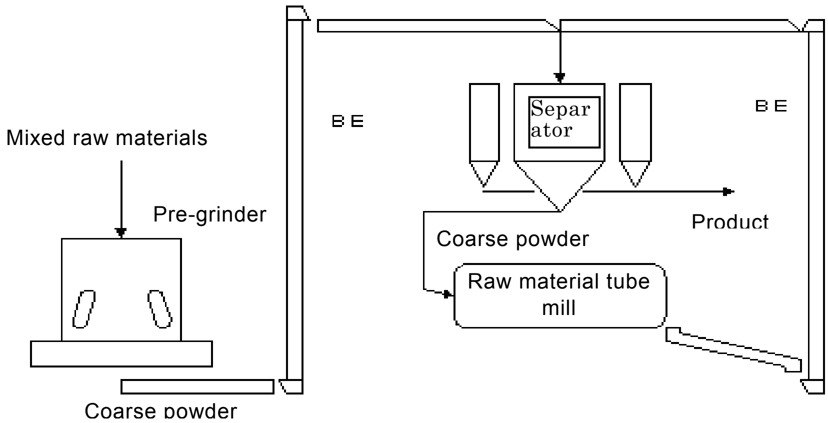


Fig. Raw material grinding system

Results

Table Effect of implementing raw material pre-grinder

		Before implementation	After implementation	Effect
Production Rate	t-RM/h	180	354	97% up
Fineness: 88μm (residue)	%	17	22	
(Tube mill power)	kW	2550	2650	
(Pre-grinder power)	kW	—	1120	
Total power consumption	kW	2550	3770	
Specific power consumption of tube mill only	kWh/t-RM	14.2	10.6	25% down
Departmental power consumption rate	kWh/t-RM	34.3	26.6	22% down

By this production increasing, it is expected that operation in the daytime can be shortened and then power cost can be reduced.

Cost estimation

About 7.3 million US$ (depending on the scale) [1US$=¥110]

Related matters

Reference

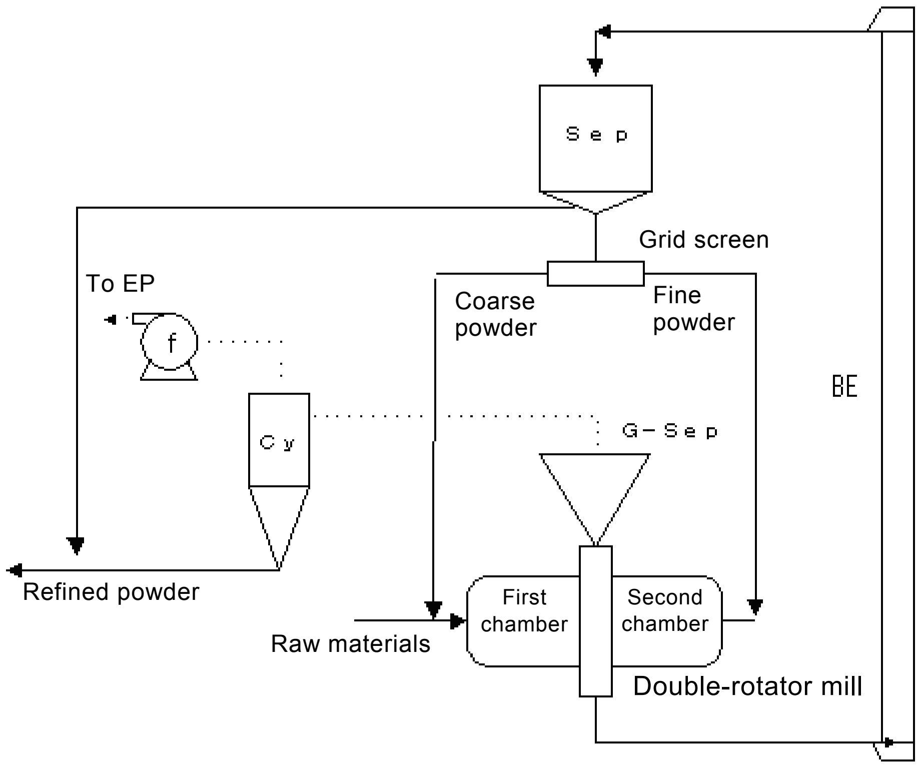
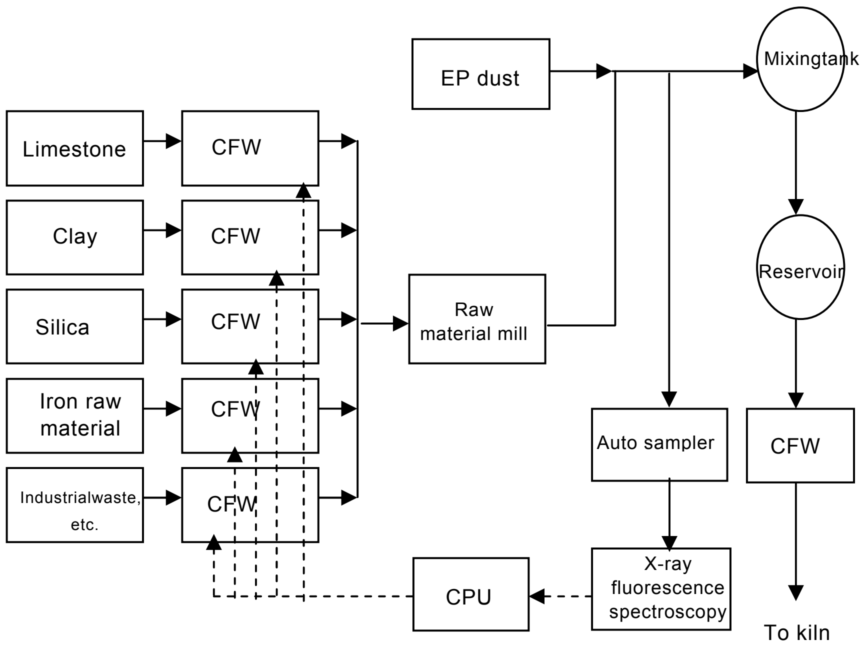
<table>
<tr><td>Item</td><td>Classification of powder returned from raw material separator</td><td>Application process
Raw material process</td></tr>
<tr><td>Background</td><td colspan="2">When raw materials are ground in a closed circuit by a double-rotator mill, grids remain underground in the second chamber for fine grinding, lowering the grinding efficiency.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The cause of this phenomenon is that grids contained in the separator returned power directly enters the second chamber. To separate grids from the returned powder and return them to the first chamber for coarse grinding, a simple grid screen (classifier) was installed at the return chute of the separator. The grids and coarse powder were ground with large balls. The ball diameter of the second chamber can be made small because only fine powder is returned to the room.


Fig. Classification of returned powder by double-rotator mill</td></tr>
<tr><td>Results</td><td colspan="2">The work for removing grids from the second chamber can be mitigated. The decrease of power consumption rate is not remarkable but below 1 kWh per ton of raw materials.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">18,000 to 36,000 US$ per system [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Automation of raw material mixing control</td><td>Application process</td></tr>
<tr><td>Raw material process</td></tr>
<tr><td>Background</td><td colspan="2">To keep the components of continuously produced raw materials at the targets is the most basic requirement for stable operation (energy conservation) and maintaining quality of production out of the burning process.
Since the raw material mixing ratio must always be adjusted to keep the components of raw materials at the targets, an automatic control system was developed and implemented.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The basic management of the components of cement raw materials is to set the mixing ratio target based on the chemical composition of various raw materials and feed back the results of analyzing the components of raw materials and adjust precisely the mixing ratio.
Therefore, an online automatic control system was developed and implemented by combining such systems as continuous measuring equipment, an automatic sampler, an X-ray fluorescence spectrometer of the glass bead method, and a computer program for mixing control.



</td></tr>
<tr><td>Results</td><td colspan="2">1) The hydraulic modulus and other coefficients for component management become stable and the heat consumption rate creases according to the degree of improvement.
2) The clinker quality becomes stable.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">X-ray fluorescence spectrometer of the glass bead method: 0.9 to 1.8 million US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Item</td><td>Optimization of raw material fineness</td><td>Application process
Raw material process</td></tr>
<tr><td>Background</td><td colspan="2">Raw materials used to be ground to a rather finer level because the fineness of them affects the clinker burning efficiency. Since the power consumption rate is high for the fine grinding of raw materials, great efforts were made to save energy by making raw materials coarse.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The fineness of raw materials used to be controlled at the level of several percents of 90 micron residue in the old wet process or others. As the burning method changed to SP and NSP, efforts were made to reduce the power consumption rate at the raw material process by increasing coarseness. These efforts resulted in great achievements.
Since the fineness of raw materials affects the formation of hydraulic minerals at burning, increasing coarseness is naturally limited. If raw materials are made too coarse, however, free limes are likely to increase in clinkers and more heat is required to maintain the conventional level. To optimize the fineness of raw materials, therefore, it is important to find out the limit of making raw materials coarse under specific conditions.

Means of making raw materials coarse
1) Adjusting the separator
2) Converting multiple separators into single one
3) Reducing the ball filling factor of tube mill</td></tr>
<tr><td>Results</td><td colspan="2">Achievement and estimated effect: The table below gives the results of calculation by Bond's formula with the new feed size fixed.
<table>
<tr><td>Year of Survey</td><td>90-micron Residue(%)</td><td>Estimated Power Saving Effect(%)</td></tr>
<tr><td>1975</td><td>8.0</td><td>Base</td></tr>
<tr><td>1981</td><td>11.7</td><td>11</td></tr>
<tr><td>1987</td><td>15.4</td><td>17</td></tr>
<tr><td>1996</td><td>21.2</td><td>22</td></tr>
</table></td></tr>
<tr><td>Cost estimation</td><td colspan="2">Basically, the above adjustment only</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Intermittent charging of electric dust collector	Application process Raw material process

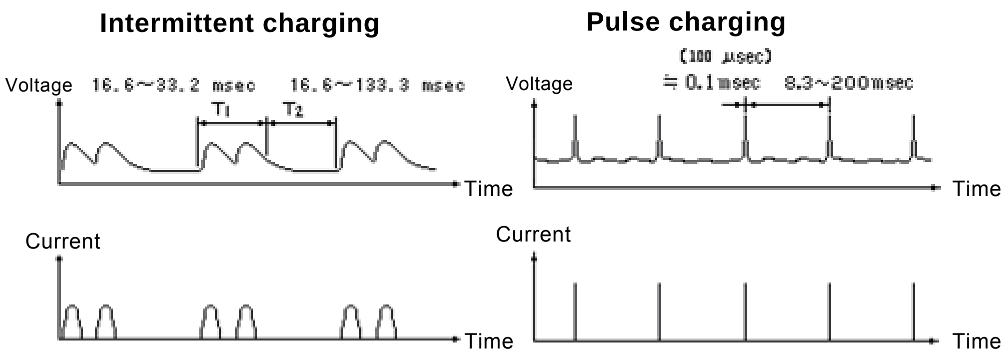
Background

The conventional electric dust collectors use the continuous charging method. However, the intermittent charging method was developed to save energy and is now being implemented.
To meet the following demand for more efficient electric dust collectors, the pulse charging method was developed and is now being implemented.

Descriptions

The intermittent charging method uses a waveform (semi-pulses) thinned out from the output of the continuous charging method periodically. Thinning out the output saves power. In addition, the dust collection efficiency is said to be a bit superior to that of the continuous charging method and the alteration cost is not high because only the control device of the continuous charging method should be altered.
The reduction of dust collection efficiency of electric dust collector became unsatisfying as coal ashes and other wastes having great electric resistance and fine particles of submicron-level diameters were used in greater amount. Under these circumstances, the pulse charging method was implemented to save power and improve the dust collection efficiency.
The pulse charging method uses a voltage waveform where pulses are superposed on a DC voltage. The DC voltage, pulse voltage, and period are controlled.
This method costs higher than the others.

As of 1996, 120 systems use continuous charging, 21 systems use intermittent charging, and 16 systems use pulse charging in Japan.



Results

		Continuous Charging	Intermittent Charging	Pulse Charging
Power Saving Effect	Ratio by Power Consumption(%)	100	65	45
Dust Collection Capacity	Ratio by Dust Collection Efficiency(%)	100	110	150

Cost estimation

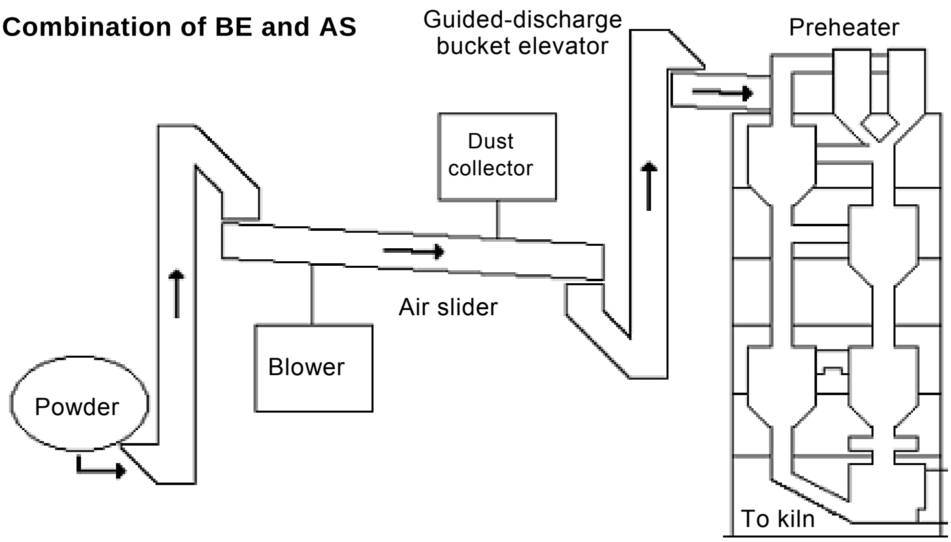
1) Conversion to the intermittent charging method: 0.8 to 1.6 million US$ (electrical equipment only) [1US$=¥110]
2) Conversion to the pulse charging method: 2.3 to 4.5 million US$ [1US$=¥110]

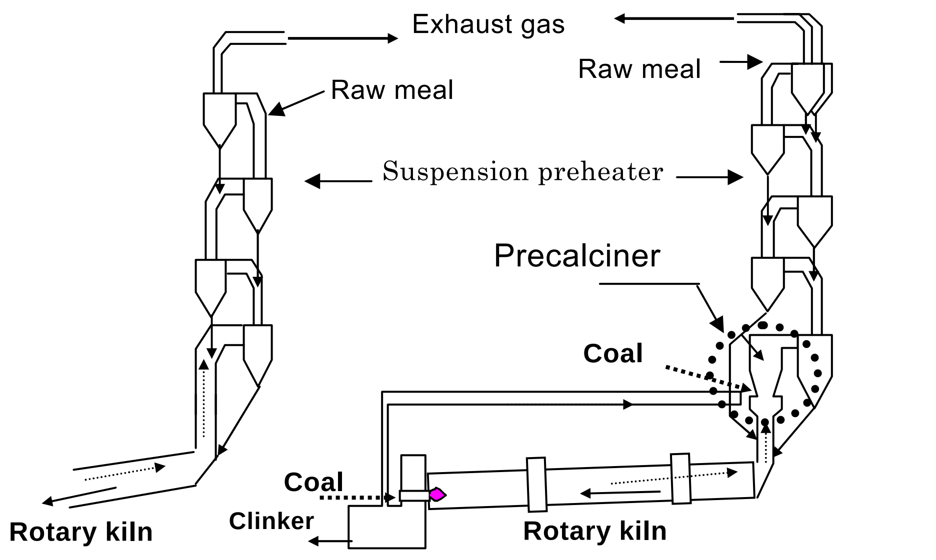
Related matters

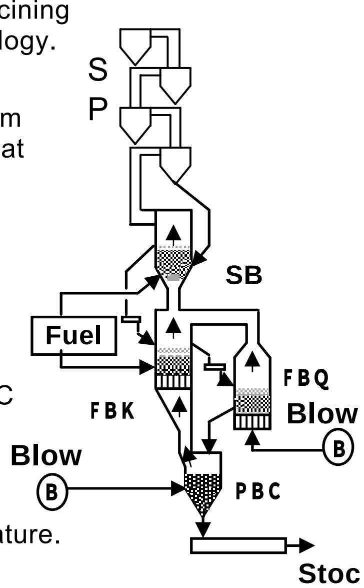
Reference

<table>
<tr><td>Item</td><td>Transportation of raw materials for input into kiln</td><td>Application process
Raw material process</td></tr>
<tr><td>Background</td><td colspan="2">For a kiln with preheater, such as SP or NSP, mixed raw materials are transported to the top of the preheater and then fed into the system. When the SP kiln was developed, air compression transpotation by a Quinion pump was initially adopted. Because of great pressure loss, high power consumption rate, and frequent compressor faults, however, a more reliable and efficient method was expected.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Compressed air transportation was replaced with mechanical transportation such as a combination of bucket elevator (BE) and air slider (AS).
Two or three Bes are installed up to the top of the preheater. Raw materials are lifted to the top by changing the Bes and fed into the preheater through the AS.
BE has small no-load power because of its structure and AS is a means of transportation using the self weight of powder. Therefore, this method can reduce power consumption greatly compared with air compression delivery.
Air compression transportation used to cause great fan power loss because of large volume of compressed air flowing into the system with raw materials. Mechanical transportation can minimize the air inflow.
The initial BE used a short-link chain that caused many problems of abrasion or elongation. A plate-type chain reduced these problems greatly and achieved the current high reliability.

As of 1996, 72 systems use mechanical transportation and two systems use air compression transportation in Japan.

Combination of BE and AS

</td></tr>
<tr><td>Results</td><td colspan="2">Mechanical transportation reduced power consumption by even 80%, although depending on the distance of transportation.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">Bucket elevator (2 units): About 1.4 million US$ [1US$=¥110]
(For a kiln having a capacity of 3000 t/d)</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	The new suspension pre-heaters burning system	Application: Burning process
Background	Clinker burning system for has switched from wet-process kilns to more efficient suspension pre-heater (SP) type since 1965. But in an SP burning furnace, all materials were fully combusted at once and this gave damage to the refractory inside. Besides with the increasing cost for maintenance, adhesion troubles in the pre-heater arouse, and it hindered from long time operation or capacity expansion.	
Descriptions	To solve those problems, a separate pre-calciner was installed within suspension pre-heater, which enabled reduction of specific energy consumption per unit clinker by 50-60%. This technology was developed and applied in Japan. With SP type burning furnace, the raw materials were only 20-30% calcined at the kiln gate. While with the NSP type, it reaches over 90%. This reduces heat energy consumption in the rotary kiln for clinker production to approximately 40-50%, enhance production level, and mitigate damage to the refractory materials in the kiln. NOx emission levels are also reduced. These days, up to 320 days operation a year became possible thanks to this technology.  **Fig.1 Suspension Preheater** **Fig.2 New Suspension Preheater**	
Results	1. Max. output increment SP type burning furnace 4,000t/d; NSP type 10,000t/d 2. Reduction in average unit consumption of energy (in calorific value) SP type burning furnace 3,470~3,600kJ/kg; NSP type 2,930～3,350kJ/kg 3. Reduction in NOx emissions compared with SP type burning furnace, due to lower combustion temperature and two-staged combustions prevailing in a precalciner 4. Reduction of specific consumption of refractory SP type burning furnace 800～900g/t-cl; NSP type 500～600g/t-cl	
Cost estimation	About 273 million US$ for new facility from “Raw material process” to “Burning process” [4000t-clinker/d] [1US$=¥110]	
Related matters		
Reference		

<table>
<tr><th>Item</th><th>Fluidized bed cement kiln system</th><th>Application
Burning process</th></tr>
<tr><td>Background</td><td colspan="2">In cement manufacturing, global environmental preservation such as the reduction of greenhouse effect gas (CO_2) emission is required in addition to the reduction of NOx and SOx emission these days. Furthermore, the cement market needs to produce special cements such as high compressive strength cement and early hardening cement.
In response to these needs, the fluidized bed cement kiln system has been researched and developed to comply with the global environment preservation since 1989.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The fluidized bed cement kiln system consists of the following equipment:
1) Suspension Preheater (SP) with Calciner (SC):
consisting of 4-stage cyclones for preheating and calcining raw materials, which applies the conventional technology.
2) Granulating kiln (SBK):
for granulating raw materials into granules of 1 to 2mm average diameter without feeding seed-core clinkers at high temperature (1300°C) level. This is the key technology of the system.
3) Sintering Kiln (FBK):
for efficiently completing the sintering of the granules produced in SBK at high temperature (1400°C) level.
4) Fluidized Bed Quenching cooler (FBQ):
for quickly cooling down the burnt clinker from 1400°C level to 1000°C in order to get good quality.
5) Packed Bed Cooler (PBC):
for efficiently recovering the sensible heat of clinker and cooling down the clinker to the specified temperature.

</td></tr>
<tr><td>Results</td><td colspan="2">1)Economic advantages
(1) Due to improvement of the burning and heat transfer characteristics, it is able to use low grade coal such as low volatile coal and low calorific coal.
(2) The heat recovery efficiency of the system can be improved by 20 % as compared with the conventional cooler due to increase of waste heat recovery.
(3) Both of construction and maintenance costs can be decreased because there are no movable apparatuses.
2) Lower environmental pollution
(1) The emission of thermal NOx emission can be greatly decreased because combustion takes place in the fluidized bed without generating flame.
(2) The emission of CO_2 can be decreased by approximately 10% due to reduction of fuel consumption and so on.
(3) The system is able to control temperature more tightly and keep a longer reaction time, and it enables the quality improvement and the production of special cement with higher grade.</td></tr>
<tr><td>Cost estimation</td><td colspan="2"></td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

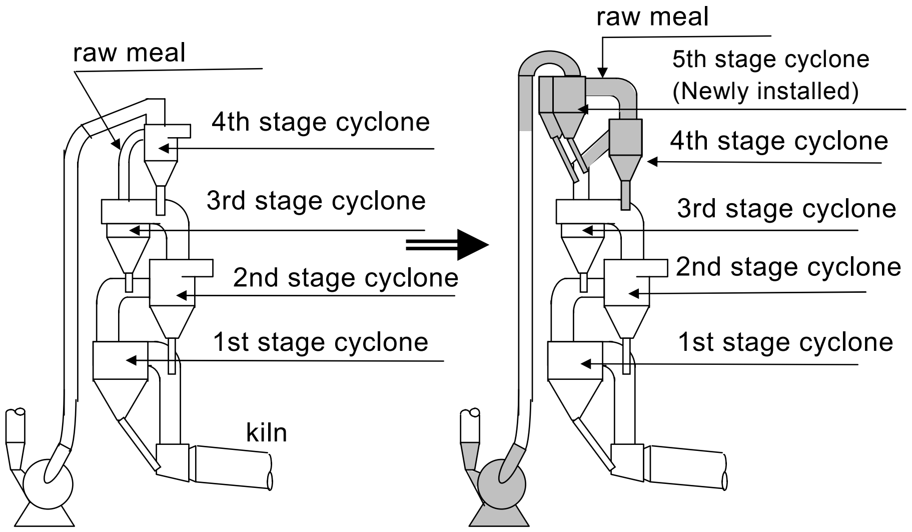
Item	5-stage system of suspension preheater	Application: Burning process
Background	The suspension pre-heater is multistage heating system, using exhaust gas. In case of 4-stage, the temperature of gas at the outlet of the pre-heater is around 400℃. This exhaust gas is used for drying raw materials. The unexploited heat is let out after himidiffication. For achieving energy saving, remodeling of pre-heater from 4-stage to 5-stage is carried out.	

Descriptions

There are two cases for 5-stage preheater. One is remodeling and the other is the adoption of 5-stage preheater in the case of new construction of kiln. By addition of one cyclone, the temperature of gas at the outlet of the preheater is decreased about 30～50℃. By adopting the 5-stage system, heat exchanging ability increases and the heat efficiency of the total system increases. As results, the specific heat consumption decreases.

This technology usually applies to small capacity kilns that power station by the waste heat is not economically applicable.

The example of remodeling



Results

Compared with 4-stage preheater, the specific thermal energy consumption decreases about 125～170kJ/kg-clinker (plant average) in case of 5-stage preheater. Ratio of 5-stage preheater is 23 percentage in 1996 [Japan].

The specific heat consumption compared with 4-stage system

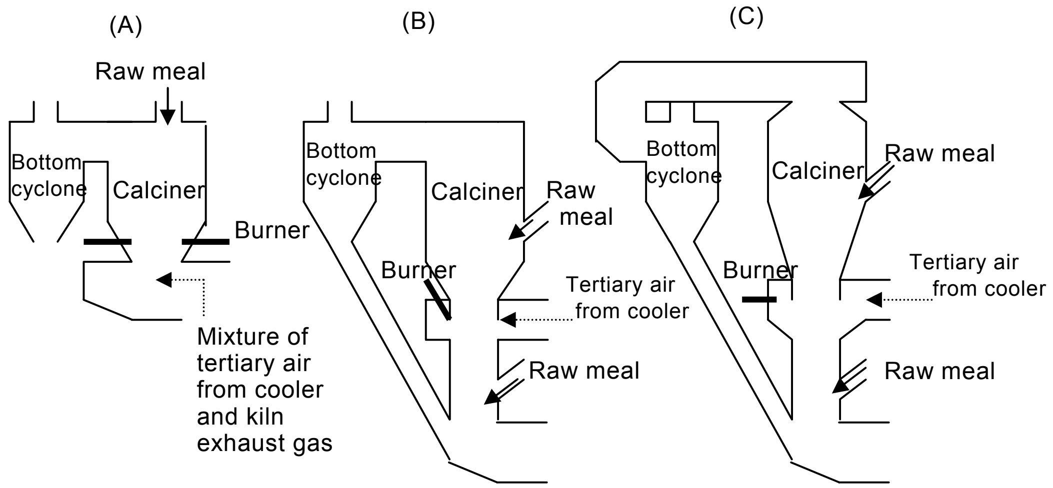
	5-stage system
NSP type	96%
SP type	95%

Cost estimation	1.4 ~2.7 million US$ for additional 1-stage cyclone [2500t-clinker/d] [1US$=¥110]
Related matters	Low-pressure-loss-cyclone
Reference	

<table>
<tr><td>Item</td><td>Improvement of the calciner</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">A calciner installed at a suspension preheater consumes about 50 to 60% of necessary heat to promote the thermal decomposition of limestone in raw materials.
When NSP was popular, the main fuel was heavy oil and the calciner was also designed according to the combustion characteristics of heavy oil but has been optimized according to the change of fossil fuel after the Oil Shock in 1970s.</td></tr>
<tr><td>Descriptions</td><td colspan="2">

1) The initial calciner that used to burn heavy oil of good combustibility did not have an enough volume to complete the combusion of pulverized coal slow to burn. (A)
2) To make pulverized coal stay long, the volume of the calciner was increased. In addition, positions of burners and a way of connecting tertiary air duct from the cooler were improved. (B)
3) Since highly volatile coal of comparatively good combustibility was mainly used in the burning, the volume of the calciner was increased only a little by making its ceiling higher. To burn less volatile coal, however, the duct was extended from the calciner to the bottom cyclone for securing enough pulverized coal combustion time. (C)

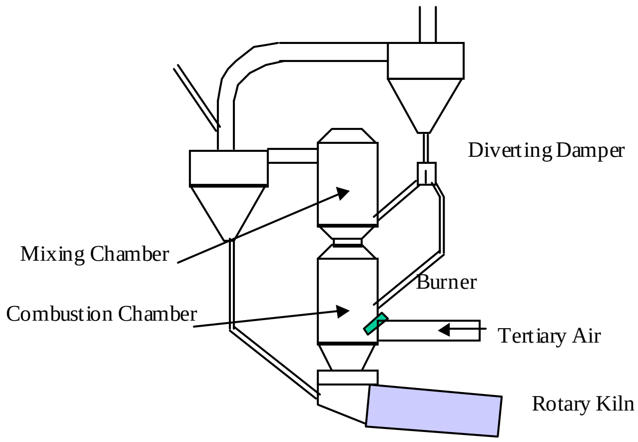
For cost reduction, the use of oil coak and other fuels of low combustibility are increasing these days. To improve their combustibility, high temperature to some extent is necessary. To improve temperature distribution in the calciner, some measures are taken: ①Making the tertiary air from the cooler hot (raising the cooler efficiency), ②Reducing the grain size of pulverized coal, and ②Raising the burner efficiency and optimizing the setting position.

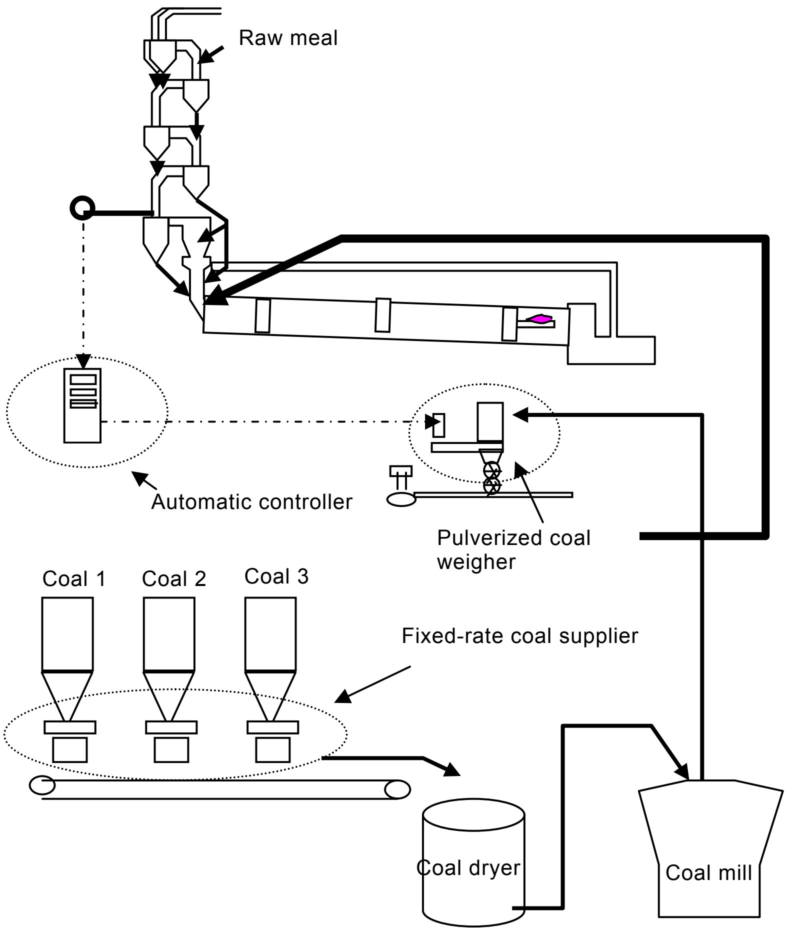


Effective volume of the calciner
V = 169 m^3 V = 230 m^3 V = 460 m^3

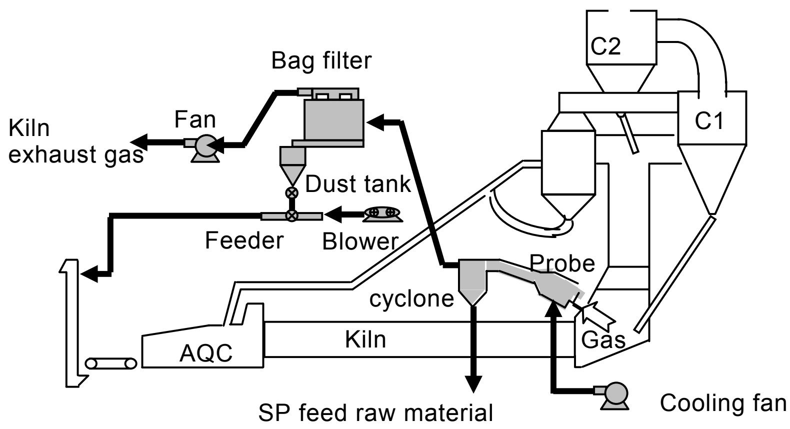
Example of improvement

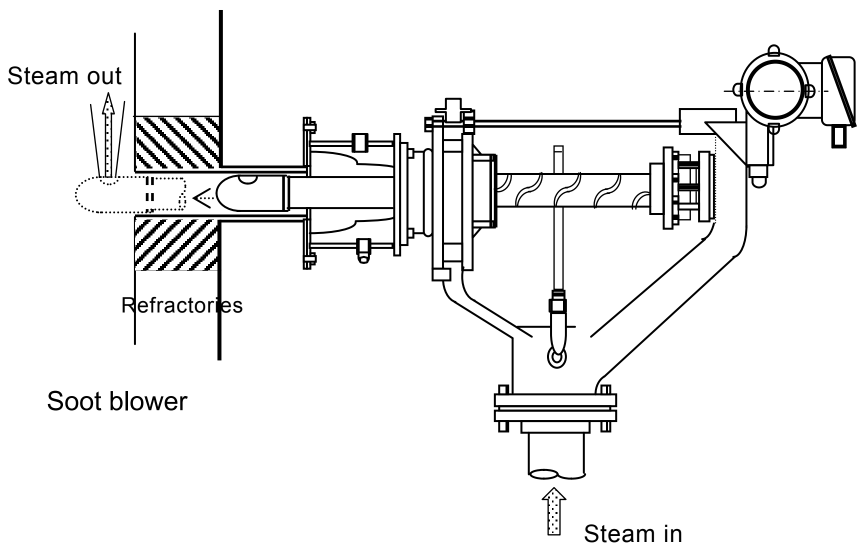
</td></tr>
<tr><td>Results</td><td colspan="2">(1) Solid fuels of the average volatile matter content from 15 to 20% can be used.
(2) The heat consumption goes down to 80 to 125 kJ/kg (20 to 30 kcal/kg) from the system of (B).</td></tr>
<tr><td>Cost estimation</td><td colspan="2">3 to 4 million US$ (Burning capacity: 3,000 t/d) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Improvement of burning in calciner</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Improvement of burning in calciner	Application Burning process
Background	For a calciner, coal of comparatively high volatility used to be used. To meet the demand for less expensive fuels, the combustion technology has been improved to use coal of low volatility.	
Descriptions	When a fuel of low volatility is used under the conditions for a fuel of high volatility, the burning temperature of the calciner falls and the outlet gas temperature of the bottom cyclone rises as the burning time becomes long. Since the production output and the heat consumption rate deteriorate, technological development was promoted to utilize a fuel of low volatility. To improve burning in a calciner, the following technologies are adopted: 1) Reducing the air ratio (solid-gas ratio) for transporting pulverized coal (Reducing the cold air blow-in rate) 2) Rising temperature of tertiary air for calciner (1) Insulation lining of the tertiary air duct for calciner (2) Improving the heat recovery efficiency of the cooler 3) Increasing the fuel fineness (1) Improving the fuel grinding mill and separator (improving the fine grinding performance and classification efficiency) 4) Changing the burner set position (for quick contact and mixing with the tertiary air) 5) Adopting a swirl vane structure for the burner (promoting fuel dispersion and ignition) 6) Securing a high-temperature combustion area in the calciner (adjusting the timing of contact with raw meal)  **Example of split raw meal feeding**	
Results	1) A fuel of low combustibility does not deteriorate the heat consumption. 2) Pulverized coal of the average volatile matter content from 15 to 20% can be used. (The fuel cost goes down.)	
Cost estimation	1) Burner alteration: 10 to 50 thousand US$ [1US$=¥110]	
Related matters	Improvement of the calciner	
Reference		

<table>
<tr><td>Item</td><td>Automatic control of bottom cyclone outlet temperature</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">For a stable kiln operation, it is necessary to keep almost constant the decomposition (decarbonization) rate of raw materials input into the kiln. The outlet temperature of the bottom cyclone is used as an operation index on behalf of the decomposition rate and the kiln is operated to keep its transition stable.
Since the outlet temperature varies with various factors, such as the fluctuation of heat value of the fuel, it is difficult to deal with all fluctuations manually. This is why technology such a automatic control was put to practical use.</td></tr>
<tr><td>Descriptions</td><td colspan="2">1) In general, the outlet temperature of the bottom cyclone is detected and the fuel supply to the calciner is automatically controlled to make the outlet temperature match the setting.
2) The outlet gas temperature of the cyclone or the outlet temperature of raw meal is used as the outlet temperature detection end.
3) The temperature is also adjusted by controlling the supply of raw materials or both the supplies of fuel and raw meal.


Outlet gas temperature control flow of bottom cyclone</td></tr>
<tr><td>Results</td><td colspan="2">The heat consumption for burning clinkers goes down by 0.8%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2"></td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Chlorine bypass system	Application Burning process
Background	Chlorine contained in cement raw materials is evaporated by a high-temperature section in the kiln and condensed at the lower part of the preheater where the temperature is comparatively low. This is repeated for condensation up to about 200 times. By reaction with raw materials, chlorine or sulfur generates various compounds of low melting points and forms scales (coating) on the internal wall of the preheater, causing such process problems as an increase of ventilation resistance and clogging in the cyclone. Drastic measures were necessary to prevent these problems from causing great energy losses.	
Descriptions	The cause of scales deposited in the preheater corresponds to the melting point of compound and the temperature distribution of the preheater. Scales in the rising duct is mainly attributed to sulfide and those in the cyclone to chloride. Their excessive resistance causes a serious problem synergetically. Chlorine bypass is a technology to efficiently recover chlorine from the lower part of the preheater where chlorine is condensed most. Raw materials are partially extracted or gas is extracted to recover fine dust. Chlorine recovery reduces the chlorine condensation in raw materials and solves or mitigates the formation of scales attributable to chlorine condensation. As of 2000, the implementation rate was 54% and the gas bypass method accounted for 80% of them. The bypass rate was 1 to 3% for 74% of the gas bypass systems and 1% or less for all of the raw material bypass systems.  **Gas bypass system**	
Results	1) Scales causing great chlorine condensation can be reduced greatly to prevent an energy or production loss. (The bottom cyclone clogging ratio is down 60% or more in most of the installed kilns.) 2) Wastes of great chlorine contents can be used more efficiently.	
Cost estimation	Chlorine bypass system for a daily output of 5,000 tons (clinker basis): About 3.2 to 4.5 million US$ [1US$=¥110]	
Related matters	Cyclone descaler	
Reference		

Item	Cyclone descaler	Application Burning process
Background	Chlorine, alkali, or sulfur contained in cement raw materials and fuels evaporates in a high-temperature section of the kiln and condenses at the lower part of the preheater. This phenomenon is repeated such elements and gradually concentrate. Reaction of these with raw meal generates various compounds of low melting points and forms scales (coating) on the internal wall of the preheater, causing such process problems as an increase of ventilation resistance and clogging in the cyclone. Various measures were taken to prevent these problems from causing great energy losses.	
Descriptions	A descaler was adopted to prevent the growth of scales deposited on the internal wall of the preheater. 1) Blowing compressed air periodically against the internal wall of the preheater (Air blaster) 2) Blowing high-pressure water or steam periodically against the internal wall of the preheater (Soot blower) The descalers are installed at many locations where manual cleaning is difficult or the scale is deposited severely and activated periodically to prevent the growth of scale.  In this example, the internal cylinder thrusts and withdraws. After thrusting, the cylinder tip rotates and blows steam out.	
Results	1) This is effective for preventing the growth of scale, but the effect differs individually. 2) The work load of preheater cleaning can be reduced.	
Cost estimation	1) Soot blower (set): About 50 thousand US$ [1US$=¥110] 2) Air blaster (set): About 8 thousand US$ [1US$=¥110]	
Related matters	Chlorine bypass system	
Reference		

<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Combustion management</td><td>Application</td></tr>
<tr><td>Burning process</td></tr>
<tr><td>Background</td><td colspan="2">The clinker burning process consumes great thermal energy to make clinker. Fuels combustion management is the most fundamental energy-saving activity to be conducted everyday at cement plants.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Combustion management approaches are made from various aspects relating to combustion.

1) Fuel management
The main fuel used in Japan is coal and its supply sources are selected, taken into consideration the price, fuel ratio (fixed carbon to volatile matter), and Hard Grobe Index (HGI).
Technically speaking, the capacities of grinding mills, performance of burners, burner performance, volume of calciner, and other items relating to fuel combustion should be considered enough at the time of selection.

2) Fuel grinding management
According to the combustion characteristics of fuels, fuel grinding should be managed to achieve fineness appropriately set. In particular, the separator should have high classification performance because the mixing of coarse particles increases non-combusted part of coal.

3) Air ratio management
For complete fuel combustion, air beyond the theoretical volume is required when actual operation is made. If too much air is supplied, however, thermal energy necessary for its heating becomes a loss. To maintain an appropriate air ratio, the oxygen concentration in the combustion exhaust gas requires strict management. Oxygen densitometers are installed at the kiln inlet, exhaust gas outlet of the preheater, etc. For gaining values, they should be checked periodically and maintained properly.

4) Exhaust gas management
In addition to the above oxygen management, CO and NOx are measured and their measurement data are used for combustion management. NOx is generally said to reflect the temperature of a burner flame but requires appropriate management because its emission concentration is regulated.

5) Kiln burner management
According to the combustion characteristics of fuels, the basic designs such as the fuel discharge angle of the burner, the primary air ratio, etc., should be reviewed to maintain the optimum combustion conditions. Even during operation, it is necessary to optimize the frame shape by changing the burner set position, adjusting the primary air ratio, etc. according to a fuel change.

6) Cooler operation management
Heat recovery at the cooler greatly affects the combustion management of the kiln burner. Therefore, scheduled maintenance and adjustment and management in everyday operation are important.</td></tr>
<tr><td>Results</td><td colspan="2">The thermal energy utilization efficiency is improved. (The heat consumption goes down.)</td></tr>
<tr><td>Cost estimation</td><td colspan="2"></td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Stabilization of coating in kiln	Application Burning process
Background	Coating formed on the brick working surface in the kiln burning zone lowers the shell temperature to reduce radiant heat and protects the brick. Unstable coating easily leads to a brick problem and generates an energy loss by disturbing stable run.	
Descriptions	Various measures are taken to form and maintain stable coating in the kiln burning zone. 1) Preventing fluctuation of components in raw meal One of the causes of unstable coating is the fluctuation of components in supplied raw meal. For a kiln of unstable coating in the burning zone, the fluctuation of components in raw meal should be checked and corrective measures should be taken if the fluctuation is great. 2) Preventing the fluctuation of fuel combustion status If the fuel is changed unreadily to a brand of greatly different combustion characteristics, the frame pattern will change greatly and the coating may break. It is also important to prevent the blow-in rate from fluctuating. 3) Preventing kiln hunching Where the burning conditions change periodically, breakage of coating easily occurs. Since hunching is often attributable to the fluctuation of the clinker cooler, it is necessary to stabilize the cooler operationj 4) Improving the kiln burner If the combustion performance of the kiln burner is low, coating generally does not adhere and easily breaks from a slight heat shock. If coating comes off frequently, the burner performance should also be noted. 5) Selecting quality of bricks The deposition of coating also differs depending on the brick quality. The lining position should be determined by considering that spinel bricks are less adhesive than magnesia-chrome bricks. 6) Cooling the kiln shell Coating is considered to form when liquid-phase mineral of high temperature contacts with and cooled by the brick working surface and becomes solid. It is thought that coating deposition can be strengthened by cooling the shell temperature forcibly to reduce the temperature of the brick working surface. Both air cooling and water cooling are in practical use.	
Results	1) Radiation heat is reduced. 2) Brick abrasion is mitigated (to prevent brick problems).	
Cost estimation	Kiln shell air-cooling equipment: about 91 thousand US$ [1US$=¥110]	
Related matters		
Reference		

<table>
<tr><td>Item</td><td>Strengthened air sealing at kiln outlet</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">The kiln outlet shell is structurally a free end under very severe thermal conditions, being exposed to high-temperature clinker and radiant heat from the refractories in the cooler hood. If the outlet shell has cracks, opens a bell shape and causes a great losses like a kiln stoppage by bricks drop.
To protect the kiln outlet shell, the lining refractory of appropriate quality, fixing tip casting, and forced air cooling is adopted in general. If air sealing at the outlet is not adequate, cool air leaks into the cooler, lowers the secondary air temperature, and deteriorates the heat consumption.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The kiln outlet has a dual-shell structure where forced cooling is made by air from an exclusive fan or branched fan from a cooling fan of the clinker cooler.
To prevent part of the air after heat exchange from leaking into the cooler and lowering the secondary air temperature, a spring-type seal or brush type air seal is adopted.

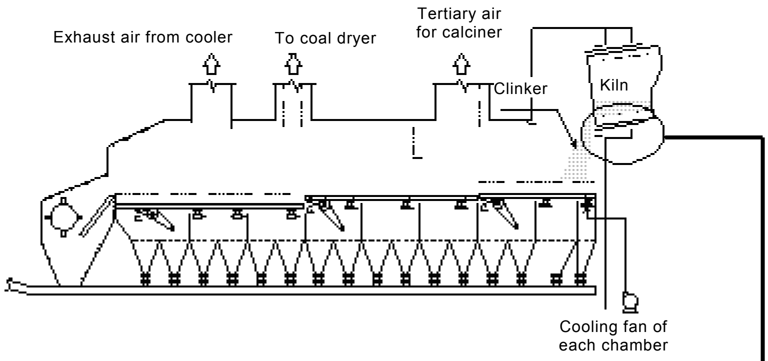
Air leakage at the kiln outlet produces a much greater influence than that at any other section because it not only lowers the combustion efficiency of the burner but also increases the fuel consumption to heat the leaked air.
Air leakage at the outlet must be minimized.


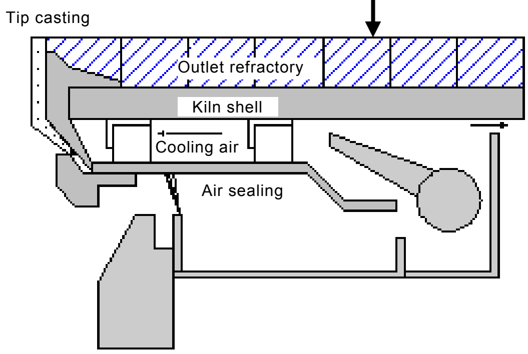
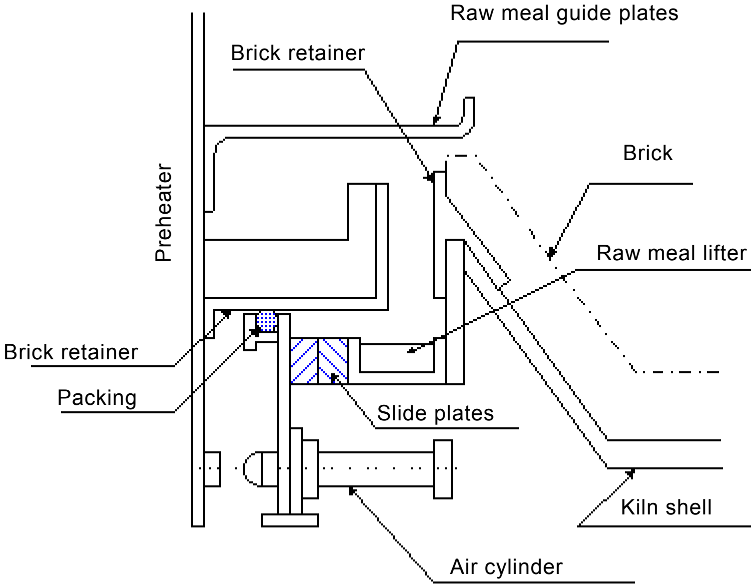
Fig.1 Schematic of the kiln mouth


Fig.2 Air seal at the kiln outlet (Brush type air seal)

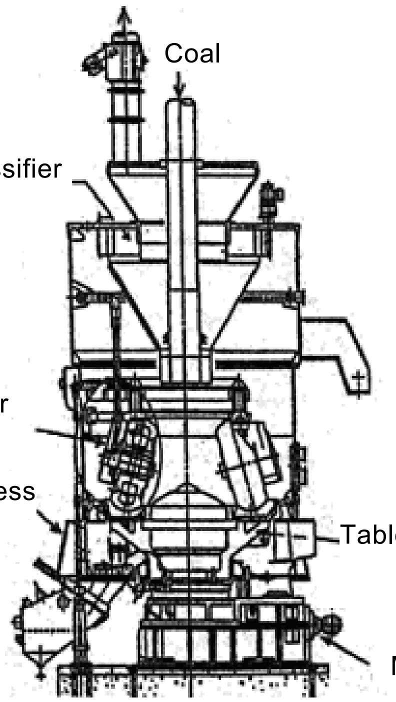
As kiln outlet refractories, refractory castables and fired spinel bricks are popular. SCH13 occupies the greatest percentage used for the tip casting.</td></tr>
<tr><td>Results</td><td colspan="2">As the leaked air was reduced by 160Nm^3/min, the heat consumption became about 42 kJ/kg-cl (10 kcal/kg-cl) less.</td></tr>
<tr><td>Cost estimations</td><td colspan="2">50 thousand US$ (5,000t/d) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

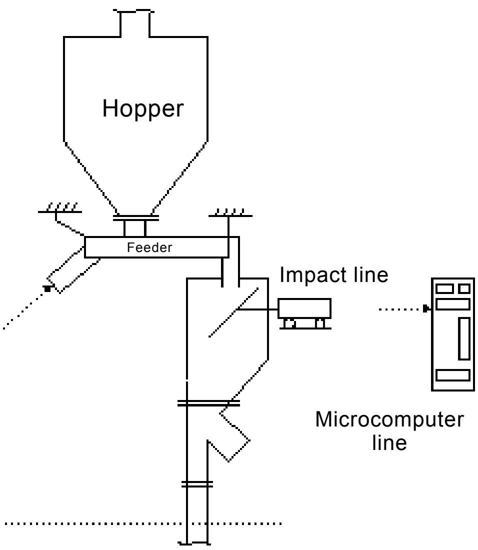
<table>
<tr><td>Item</td><td>Strengthened air sealing at kiln inlet</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">Air leakage into the cement manufacturing process deteriorates the heat and power consumption. Since the air leakage at the inlet of the kiln cools high-temperature combustion exhaust gas and lowers the heat value greatly, it is important to prevent air from leaking in.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Air sealing at the inlet of the kiln has a structure to mechanically prevent kiln shell rotation and thermal expansion from causing a gap. The figure shows an example of air sealing structure.

1) Air is sealed by the slide plates installed on the preheater side and the kiln side.
2) The slide plates are always pressed against each other by the air pressure of the air cylinder.
3) The slide plates have greasing holes to strengthen the airtightness and prevent their abrasion.
4) The slide plates on the kiln side have raw meal lifting device (boxes or plates) to prevent the leakage of raw meal.



Structure of air sealing at the kiln bottom</td></tr>
<tr><td>Results</td><td colspan="2">The deterioration of heat and power consumption is prevented.</td></tr>
<tr><td>Cost estimations</td><td colspan="2">0.2 million US$ (kiln diameter: 6 m) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Item</td><td>Vertical coal mill</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">Tube mill had been used for coal grinding. Steel balls were used as the grinding media, and tube mill should have enough room to allow attrition between the balls and coal. This result in higher initial costs, higher electricity consumptions and limits the downsizing of the tube mill.</td></tr>
<tr><td>Descriptions</td><td colspan="2">In a vertical coal mill, drying, grinding, and separating/classifying of coal can be done simultaneously. Hence, production and energy efficiency is higher. This technology became popular after oil shock time, when the fuel switched from oil to coil.
1. Wet coal is feed from the upper part or side of the mill onto the rotating table.
2. It was then crushed and ground by the pressing of the steel roller.
3. Fine coal particles are dried and swept away into the separator by a high velocity of hot air flow from the bottom of the mill.
4. Separated fine coal particles are captured by a bag filter and used as fuel.

</td></tr>
<tr><td>Results</td><td colspan="2">Capable of reducing electricity consumptions for coal grinding by 20-25%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">About 9 million US$ including cost of supplemental facilities [20t-coal/h]
[1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Pulverized coal constant feeder	Application: Burning process
Background	The accuracy of constantly feeding pulverized coal to a cement rotary kiln affects the stability of the burning process and the cement quality. The selection and daily maintenance of feeding and measuring devices are extremely important.	
Descriptions	The constant feeders for pulverized coal now used in Japan can be classified into the following types. Both types feature high feeding accuracy within ±1% and high momentary accuracy as well. 1) Table type This is a combination of a volumetric table feeder and a weighing hopper that calculates the table feeder discharged amount from the weight reduction speed of the table feeder for constant feed. There is a horizontal rotation table under the hopper. Pulverized coal on the table is scraped off by the scraper board while being rotated with the table. The feed amount is adjusted by the press-in depth of the scraper board. 2) Screw + impact line type The impact flowmeter is based on the principle that the horizontal component with impaction force of naturally falling pulverized coal on the detection plate is proportional to the momentary weight flow rate. An impact flowmeter is combined with a screw feeder which enables constant feeding by controlling the screw feeder rotation speed. 3) Table + impact line type An impact flowmeter is combined with a table feeder which enables constant feeding by controlling the table feeder rotation speed. 4) Loop conveyor scale type A loop-shaped conveyor itself has a balance structure. This conveyor has a powder inlet on one side and a powder outlet on the other side with both ends of the centerline as fulcrums. Since the mechanical structure of either sides of the fulcrum is uniform, the tare is canceled.  **Figure: Constant feeder (impact flowmeter)**	
Results	Stable constant feed free of flushing or pulsation is realized.	
Cost estimation		
Related matters		
Reference		

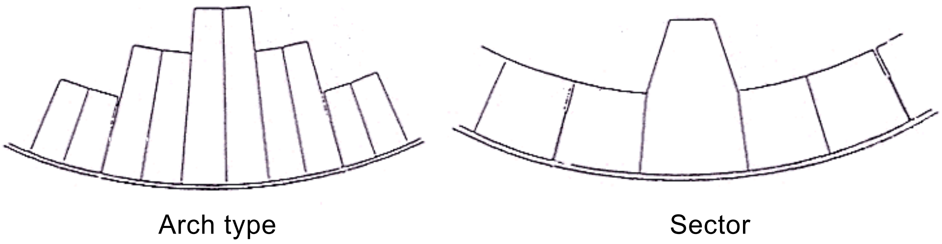
<table>
<tr><th>Item</th><th>Adoption of lifter brick</th><th>Application
Burning process</th></tr>
<tr><td>Background</td><td colspan="2">To improve thermal efficiency in the calcinating zone of a kiln and to prevent the deposition of coating to the preheater by a temperature decrease of the kiln bottom gas, four or more bricks are projected per circle to stir raw materials.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Four or more lifter bricks per circle are projecting 100 to 200 mm out of the base bricks in the calcinating zone to stir raw materials and promote their heat exchange. In addition, the full conduction of thermal energy to raw materials is expected to lower the kiln bottom temperature and reduce coating deposition to the preheater. As shown in Fig.1, the lifter brick have an arc shape when the base bricks have an arc shape or a sector shape when the base bricks have a sector shape.
Since the lifter bricks are projecting out of the base bricks, their projections easily crack or spall due to abrasion, thermal stress, or mechanical stress. Therefore, the service lives of lifter bricks have been extended by improving the material.
Regarding the number of lifter bricks per circle, there must always be lifter bricks in the raw material beds as shown in Fig.2 because they must stir raw materials without letting them slip on the bricks in the kiln. If the filling factor of raw materials in the kiln is assumed to be 10%, the central angle of the raw materials is about 90°. Then at least four or more lifter bricks are necessary per circle. (As the kiln diameter is greater, more lifter bricks are necessary.)
The lifter brick installation is mainly 2 to 10 m. The locations are not fixed but usually almost from 0.1 to 0.4 if the kiln bottom is 0 and the kiln mouth is 1.


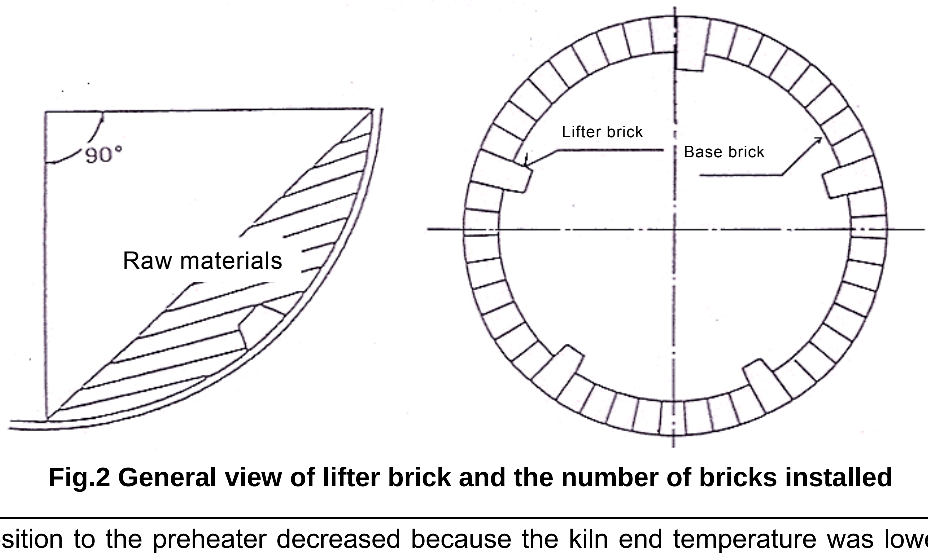
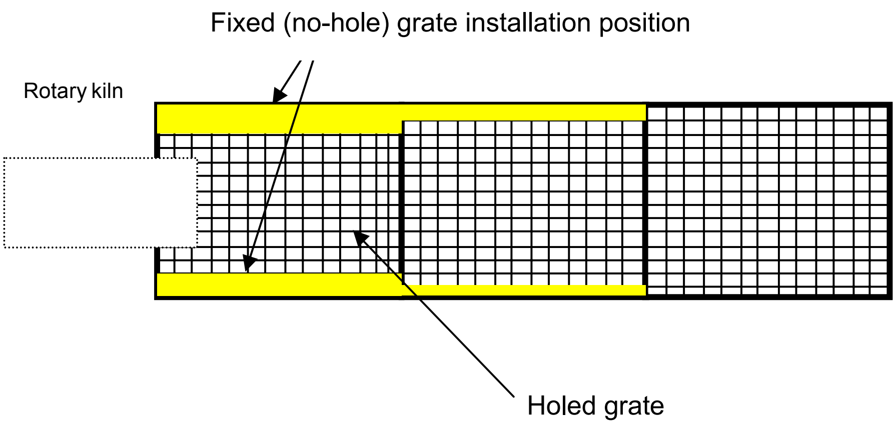
Fig.1 Lifter brick shapes


Fig.2 General view of lifter brick and the number of bricks installed</td></tr>
<tr><td>Results</td><td colspan="2">Deposition to the preheater decreased because the kiln end temperature was lowered 50 to 100°C.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">Usually high-alumina brick = 640 to 820 US$ [1US$=¥110]
Lifter brick = 1,800 to 2,700 US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Heat insulation of refractories	Application Burning process
Background	For high-temperature burning in the burning process, reftractories are used for the internal walls of various facilities. Various heat insulation measures are taken to prevent heat radiation losses from walls.	
Descriptions	The heat dissipation loss at the burning process corresponds to about 4% to 6% of the thermal energy. To reduce this loss, heat insulation measures are taken according to each section. 1) Kiln burning zone In this zone, burnt products are the hottest and coating is deposited on the surfaces of refractories (bricks) to protect the bricks and insulate heat. Therefore, the heat insulation measures in this zone is to form and maintain stable coating. 2) Kiln deposit/defoliation zone In this zone where coating is frequently deposited and defoliated, spinel bricks of great thermal conductivity advantageous for long-life bricks are often used and the shell temperature is high. Therefore, the following measures were aggressively attempted to insulate spinel bricks thermally. 1. High porosity: Raising the brick porosity to lower the thermal conductivity 2. Double-layer structure: Double-layer brick made of different materials on the high and low temperature sides 3. Attachment: Attaching a heat insulator partially to the back of the low temperature side All of the above measures, however, have a problem in life and almost none of them is now in use. 3) Kiln calcining zone For the calcinating zone of comparatively low temperature, refractory heat-insulating bricks of low thermal conductivity are used, as well as the conventional refractory bricks made of high alumina or clay. The refractory heat-insulating bricks are also burnt or not burnt according to the purpose of use. 4) Preheater Excluding the lower part of the preheater where the temperature is comparatively high, the two-layer structure is used with heat-insulating castables on the back. A wet spraying process for castables was recently developed and the construction efficiency is being improved. 5) Cooler and extraction air duct Two-layer heat insulation is applied with a heat insulator of calcium silicate on the back.	
Results	Heat dissipation decreased with a decrease of the kiln surface temperature.	
Cost estimation		
Related matters	Stabilization of coating in kiln	
Reference		

Item	Cooler width control	Application Burning process
Background	With a production capacity increase by the implementation of the SP and NSP methods, the grate-type clinker cooler also became large. Since the effective width of the cooler was too large for the clinker drop width, the problems of cooling air blowing through and heat spot occurred simultaneously. The blow-through problem lowers the secondary air temperature and the heat spot damages the grates. To prevent these problems from disabling stable run, the cooler was altered.	
Descriptions	As a solution to these problems, width control was attempted to adjust the substantially effective width of the cooler appropriately. Through a lot of experiences, individual companies have established their unique technologies. 1) The effective width of the cooler should be set appropriately by comprehensively considering the clinker load, the cooler length, the cooling blow rate in each air room, and the ability of each cooling fan. Experience in actual operation is also an important factor for this judgment. 2) General width control is for the clinker layer thickness of 500 to 800 mm at a grate driving speed not mechanically difficult. 3) It is also necessary to determine a width control position. By considering the unevenness of grain size caused by a drop from the kiln, width control on the fine stream side should be stronger. Width control is a basic technology to optimize a grate cooler of the air chamber type. However, the same concept applies to the air-beam cooler recently becoming prevalent.  **Figure: Width control (arrangement of holed grates and fixed grates with no holes)**	
Results	1) Heat recovery efficiency was improved by preventing the blow-through of cooling air (heat consumption rate down). 2) Grate burn is prevented.	
Cost estimation	64,000 US$ [1US$=¥110]	
Related matters	Automatic AQC speed control Air-beam cooler	
Reference		

<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Automatic control of
AQC grating speed</td><td>Application</td></tr>
<tr><td>Burning process</td></tr>
<tr><td>Background</td><td colspan="2">Recovering the hot secondary air and transporting clinkers are the two important functions of a clinker cooler. For the balanced execution of these two functions, it is necessary to always maintain the clinker layer of appropriate thickness on grates.</td></tr>
<tr><td>Descriptions</td><td colspan="2">1) With the wind pressure in Chamber 1 of the cooler as a substitute characteristic for the clinker layer thickness on grates, the driving speed of Level 1 grates is automatically controlled to keep the wind pressure always at the setting.

2) Under this control, if the clinker properties change, the response may become sensitive. Therefore, step control with insensitive zones may be combined and the control method may be switched according to the cooler status.

3) The volume of clinker transportation changes with the driving speed of Level 1 grates. To keep the clinker layer thickness constant, the proportional control of grate driving speed with a time delay in mind is applied to the grates of Levels 2 and 3.

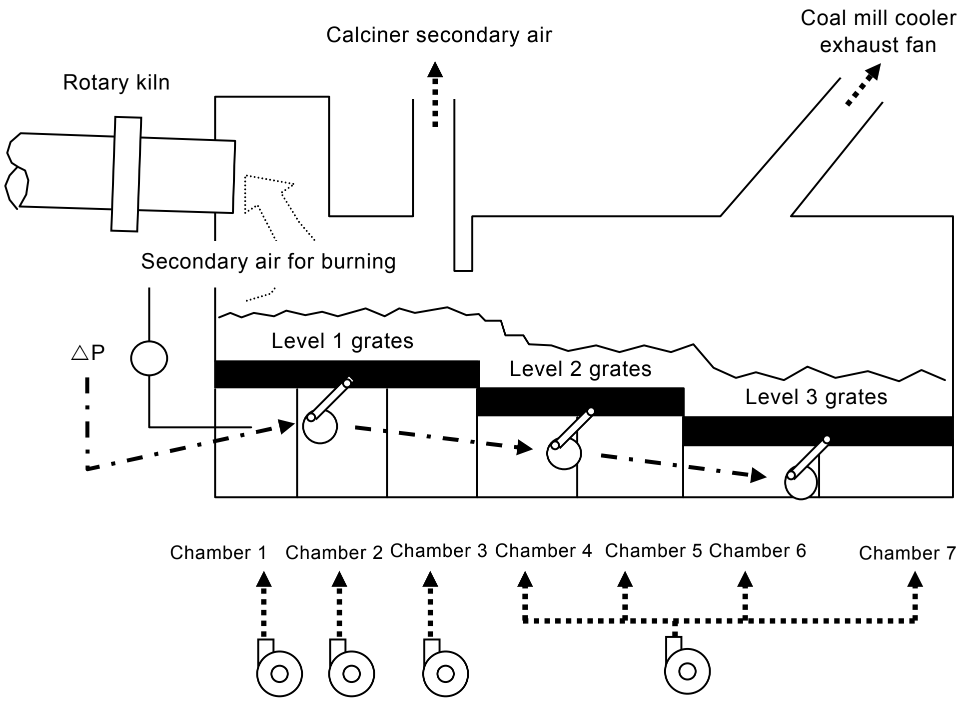


Figure: Outline of automatic AQC speed control</td></tr>
<tr><td>Results</td><td colspan="2">The thermal recovery efficiency was improved by maintaining appropriate layer thickness (heat consumption rate down).</td></tr>
<tr><td>Cost estimation</td><td colspan="2"></td></tr>
<tr><td>Related matters</td><td colspan="2">Cooler width control</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><th>Item</th><th>Installation of partition plates</th><th>Application
Burning process</th></tr>
<tr><td>Background</td><td colspan="2">A clinker cooler is divided into an area where cooling air equivalent of the necessary air volume is blown in (hereinafter, the secondary air recovery zone) and the succeeding area (hereinafter, the exhaust heat recovery zone). To recover the secondary air of high temperature in the clinker cooler, the efficiency of heat recovery from the former area should be maximized.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Since the hot clinkers on grates are cooled from the lower layer, the top of the clinker layer remains hot in the secondary air recovery zone and dissipates heat much by radiation.
1) To gather this radiant heat in the secondary air recovery zone and use it for heating the secondary air, a partition plate is installed at the border between the secondary air recovery zone and the exhaust heat recovery zone.
2) A partition plate is installed each behind the air extraction port for calciner and above the rear end of Level 1 grates. Partition plates are generally fixed but may also be movable or hanged.

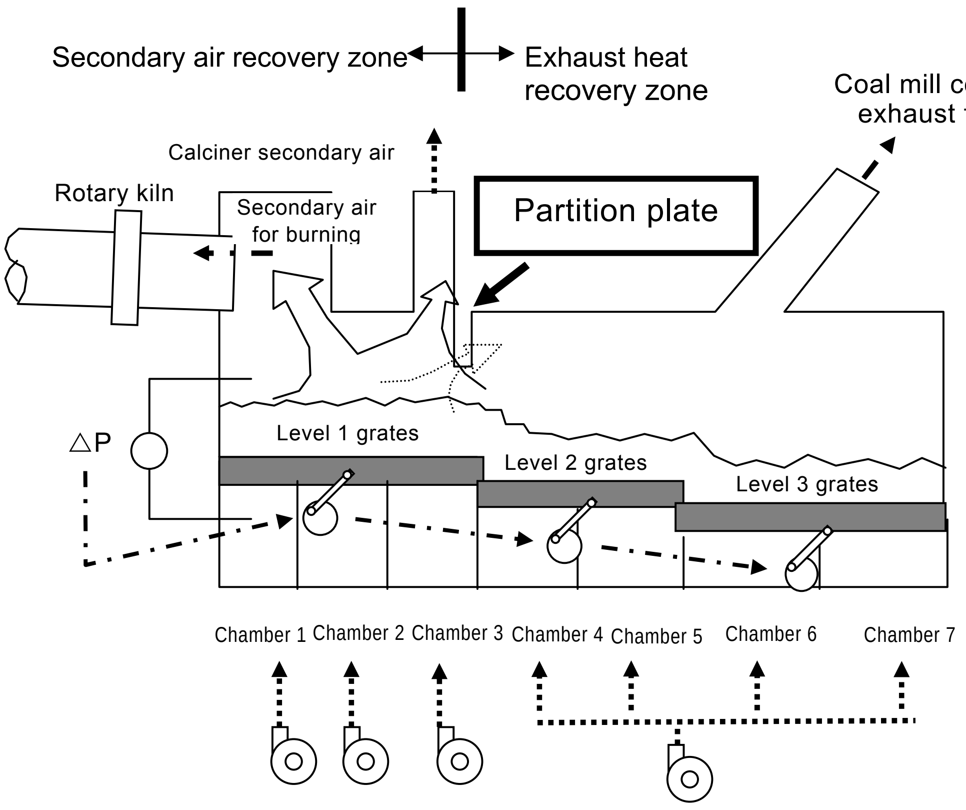
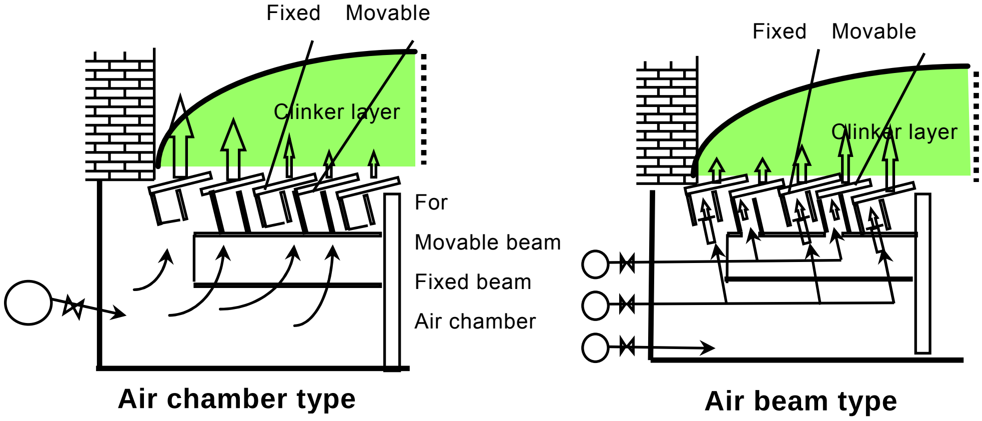
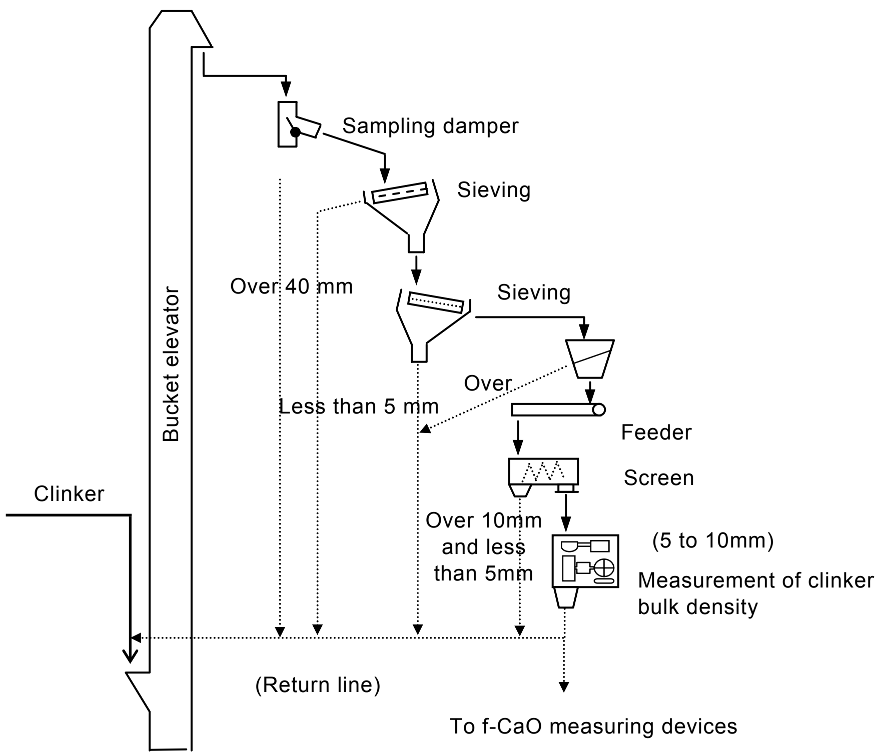


Figure: Installation of AQC partition plates</td></tr>
<tr><td>Results</td><td colspan="2">The thermal recovery efficiency was improved by maintaining appropriate layer thickness (heat consumption rate down).</td></tr>
<tr><td>Cost estimation</td><td colspan="2">45,000 US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Cooler width control</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Air beam type clinker cooler	Application: Burning process
Background	Improvement of heat recovery rate for secondary or tertiary air from the heat in clinker is one of the most important technologies in the burning process. As heat recovery rate in conventional grate coolers are approximately 50 to 60 %, more improvement has been desired.	
Descriptions	When high temperature clinker is dropped on the grate of cooler from the outlet of kiln, it is not in flat or balanced. With the conventional cooler, cooling air is supplied to each air chambers, therefore, improvement of heat recovery rate is limited by imbalance of cooling air. This problem is solved by installing air beam type cooler which has unique point as follows; 1) Cooling air is supplied directly to each block that is constructed by 4 to 8 pieces of grate plate. 2) The grate plate is structured, as more air tight and fined clinker is not able to spill down through grate. 3) This type of grate can be installed to the part of kiln outlet or main heat recovery area. As cooling air is controlled for each block, air distribution can be optimized. Therefore, heat recovery rate is improved and the life of grate plate is extended. By 2000, these types of coolers have been installed into approx. 30% of Japanese cement plants. Most of them (71%) have been installed at kiln outlet part of existing cooler. For 57% of these cases, improved heat recovery rate is not more than 5 %. In case only installed at kiln outlet part, improvement rate cannot be adequate.  **Comparison of cooling air supply**	
Results	1) Heat consumption: Approx. 42 – 167 kJ/kg decrease 2) Power consumption: Approx. 0.5 – 1.5 kWh/t decrease 3) Maintenance cost of grate plate: decrease (Extension of life)	
Cost estimation	About 2.7 ~4.5 million US$ for 1-stage cooler retrofitting [1US$=¥110]	
Related matters		
Reference		

Item	Automatic measuring device for free lime in clinker	Application: Burning process
Background	As well as the bulk density (liter-weight) of clinker, free lime (herein after, f-CaO) content in clinkers is an important factor to know clinker quality and clinkering conditions. f-CaO measurement used to be performed a few times a day by chemical analysis method. However, implementing an automatic measuring device remarkably increases the measuring frequency to 24 times a day or more. The volume of information about the clinker quality and clinker condition increases. By reflecting this information, stabilization of clinker quality can be gotten and then heat consumption of the kiln process can be reduced.	
Descriptions	For the automatic online measurement of f-CaO in clinkers, the following two methods are known: 1) X-ray diffraction method This method is based on a technology developed in Japan. Prepared representative clinker sample are ground into fine particles and molded by press. Then the diffraction strength of CaO is measured by using an X-ray diffraction device to determine the f-CaO concentration (content). In this method, clinker chemical components can be analyzed from same molded sample on X-ray fluorescence spectrometer. Unlike the chemical analysis method or electrical conductivity method, no chemical agents (solvents) are necessary for treatment. 2) Electrical conductivity method (1) Principle of measurement f-CaO in clinkers is dissolved into the ethylene glycol solvent by the following reaction: $CaO + (CH_2OH)_2 \rightarrow Ca_2^{+} + (CH_2O)_2^{2-} + H_2O$ Ca^{2+} and $(CH_2O)_2^{2-}$ give conductivity to the solution. Since these ions indicate conductivity proportional to the concentration, the amount of f-CaO in clinkers can be estimated by measuring the conductivity. (2) Outline of system Prepared representative clinker sample is transported to a f-CaO measuring device and ground by a disk mill. Fixed amounts of the clinker powder and the ethylene glycol solvent are put into beaker and the electrical conductivity is measured.	
Results	By reflecting the tendency of f-CaO data transition in running operation, the clinker quality can be stabilized and the kiln heat consumption rate can be reduced. As of Year 2000, the implementation rate is 35% (electrical conductivity method: 57%, X-ray diffraction method: 43%).	
Cost estimation	(1) X-ray diffraction method: About 460 thousand US$ (Kiln capacity: 5,000 t/d) [1US$=¥110] (2) Electrical conductivity method: About 410 thousand US$ (Kiln capacity: 5,000 t/d) [1US$=¥110]	
Related matters	Automatic measurement of clinker bulk density (liter-weight)	
Reference		

<table>
<tr><td>Item</td><td>Automatic measuring device for clinker bulk density (liter-weight)</td><td>Application
Burning process</td></tr>
<tr><td>Background</td><td colspan="2">Keeping the clinker quality constant is important factor for getting better and stable cement product. Because the value of clinker bulk density (liter-weight) shows or reflects kiln burning conditions and clinkering conditions of materials, it is widely used as an important indicating factor for kiln operation.
However, there are problems such as accuracy of measured value and/or longer sampling interval since the works were done manually. Automatic sampling system and measurement are expected.</td></tr>
<tr><td>Descriptions</td><td colspan="2">A sampler is installed at the appropriate point of clinker transportation line. The clinker of 5 to 10mm diameter is selectively sampled with it and then pre-decided quantity of sampled clinker is automatically send to weighing vessel in order to measure the clinker bulk density. Using this measured value, kiln operator adjusts kiln operating conditions, if necessary, to keep optimum conditions.
This device is usually installed and used with automatic f-CaO measurement devices and automatic clinker chemical component measurement devices.
As of 2000, implementation rate is about 20% and most of the above devices are used on the on-line system.



Automatic measuring system for volume weight</td></tr>
<tr><td>Results</td><td colspan="2">The reliability and continuity, which is gotten by shortened sample interval, of the data of clinker bulk density are improved. And more appropriate kiln operating conditions can be gotten.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">Main unit only: About 91 thousand US$ (excluding the sampler and sample transportation system) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Automatic measuring device for free lime</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
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<table>
<tr><td>Item</td><td>Closed-circuit grinding system</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">In the initial grinding system using a tube mill, ground materials are fed into and ground in the mill and all the output from the mill is used for products.
This open-circuit grinding system required improvement both in quality and operating efficiency to solve the problem of wide grain size distribution caused by inadequate grinding and excessive grinding.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The closed-circuit grinding system is the open-circuit system with a large classifier. All ground materials are led into a separator and classified into refined powder (products) and coarse powder (return powder). The coarse powder is returned to the mill and ground again with newly-fed raw materials.
One of the important indexes to indicate the run status of the closed-circuit grinding system is the circulation ratio that is the ratio of the amount of powder returned from the separator and the newly-fed amount. The optimum value depends on the mill conditions (ball size, liner shape, and slit size), the separator’s classification performance, and the raw material characteristics (clinker grain size and crushability). Therefore, it is important to check the optimum value for each mill.

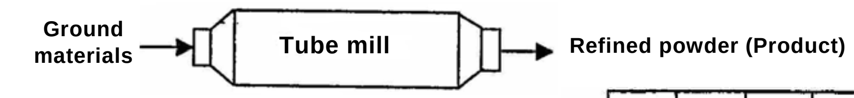


Fig.1 Open-circuit grinding system

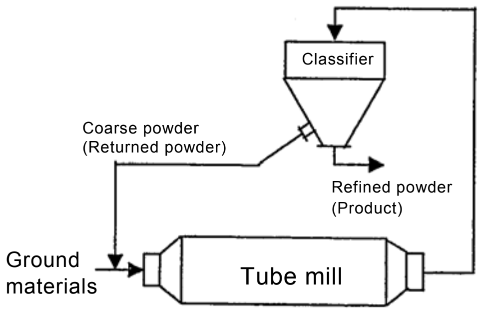


Fig.2 Closed-circuit grinding system

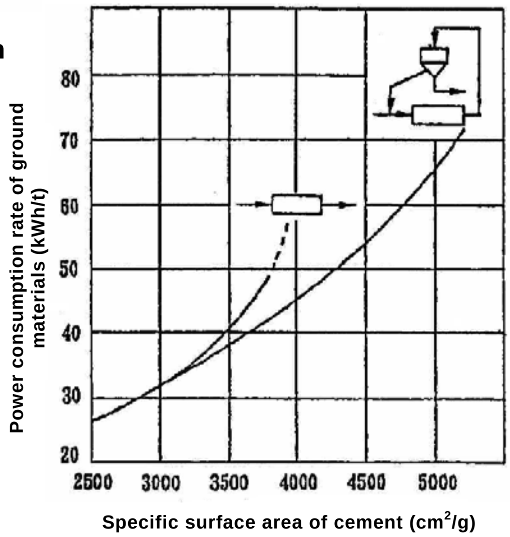


Fig.3 Power consumption rates for open-circuit and close-circuit grinding (cement grinding)</td></tr>
<tr><td>Results</td><td colspan="2">1) The grinding capacity increases.
2) The grain size distribution of refined powder becomes sharp.
3) The refined powder temperature becomes low.
4) The power consumption rate decreases.
5) The abrasion of liners and balls is suppressed.
6) The grain size distribution of products can be adjusted by changing the circulation ratio and the classifier’s run status.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">455 million US$ (3000 kW mill) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Item</td><td>Use of grinding aid</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">In general, the grinding energy efficiency of a grinder is very low. To raise the grinding efficiency, therefore, a small amount of third substance other than the grinding media and ground materials is added as a grinding aid.</td></tr>
<tr><td>Descriptions</td><td colspan="2">1) A grinding aid works as follows:
A tube mill generally loses its grinding efficiency remarkably at fine grinding. This is because fine particles from ground materials agglomerate and adhere to the mill liners or grinding media as coating, reducing the impulsive force of the mill. In addition, the agglomerated particles are mixed into the coarse powder in the separator and recirculated throughout the mill. There are various theories about the cause of agglomeration. The most convincing theory is that destruction in a crystal grain by alite biases the polarity of the fractured surface. A grinding aid prevents this agglomeration to improve the grinding efficiency.

2) There are many substances that improve the grinding efficiency. For actual use, however, the following conditions must be satisfied:
(1) The price is reasonable for the grinding costs.
(2) The substance is not detrimental to the product quality but improves it instead.
(3) Diethylene glycol is used most widely as a grinding aid satisfying the above conditions.
(4) A grinding aid is generally added to the clinkers at a fixed rate from 0.01 to 0.03% before supply to a finishing mill.</td></tr>
<tr><td>Results</td><td colspan="2">1) The grinding amount is up 4% to 6% per addition of 0.01%.
2) The aid also improved the dispersibility and fluidability of cement (powder) and delayed weathering.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">Diethylene glycol: 1,360 to 1,820 US$/kl [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

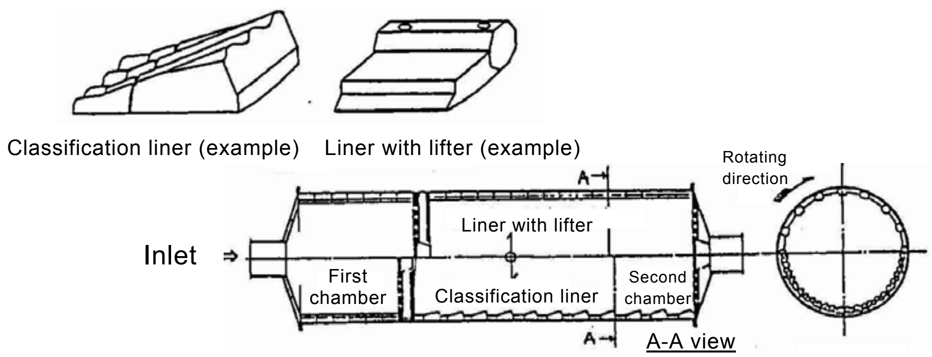
<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Classification liner for the second chamber of tube mill</td><td>Application</td></tr>
<tr><td>Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">The second chamber of a finishing mill is mainly for fine grinding. Therefore, using small balls was known to be more efficient because its increases the surface area of media and strengthen the grinding effect.
For the conventional mill using a liner with lifter, however, it was difficult to reduce the ball diameter drastically because the grinding efficiency is extremely lowered by reverse classification where small balls gather at the inlet of the second chamber and medium-sized balls gather at the outlet.</td></tr>
<tr><td>Descriptions</td><td colspan="2">To solve this reverse classification status, a classification liner was developed.
The classification liner is inclined toward the inlet of the mill to make scraped balls roll in the direction. Under the influence of the rotational force (centrifugal force) of the mill, larger balls roll toward the inlet of the mill more easily (larger balls gather at the inlet of the second chamber).
The development of this classification liner allowed small balls from 20 to 17 mm in diameter to be used for the second chamber and enabled efficient grinding without excessive grinding.
Since this liner also improved the coarse grinding capacity at the inlet of the second chamber, the grinding performance of the entire mill may improve of the first chamber is made short and the second chamber long.


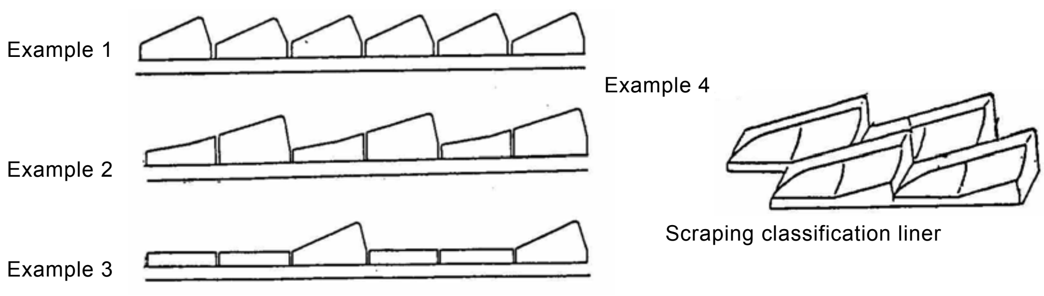
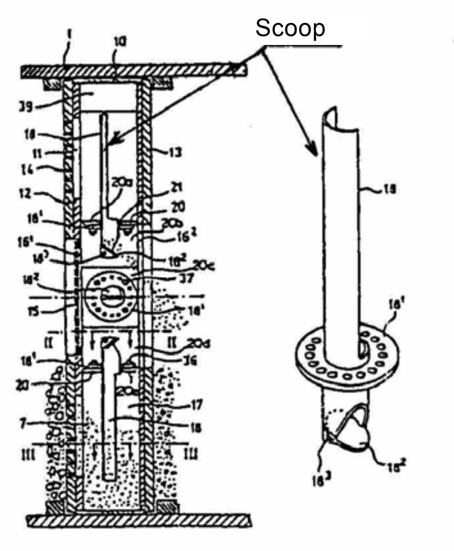
Fig.1 Classification liner and liner with lifter


Fig.2 Types of classification liner</td></tr>
<tr><td>Results</td><td colspan="2">1) The power consumption rate is down 1 to 2 kWh/t.
2) The optimum circulation ratio becomes smaller than ever and reduces load on the separator and conveyor.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">682,000 US$ (3000 kW mill) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Introduction of pre-grinder</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Item</td><td>Clinker flow rate regulator
for tube mill</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">For efficient grinding by a tube mill, it is important to secure an appropriate amount of ground materials for the balls, or to maintain the powder level.
The powder level of clinkers ground coarsely in the first chamber is affected by the aperture rate of the partition butt strap at the outlet and the slit size. In general, however, the powder level is set higher than the optimum value to prevent clogging in the mill.
Under these conditions, large balls idle and waste energy because the powder level in the first chamber is low. Since clinkers move to the second chamber before full grinding, the fine grinding efficiency in the second chamber becomes low.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The powder level can be kept optimum in the first chamber by adjusting the slit size and quantity of the partition. Since fine adjustment (clinker size) is not possible because welding takes time and the crushability (coarse grinding) changes with the conditions, a clinker flow rate regulator was implemented or developed for adjustment according to the conditions.
For clinker flow rate adjustment, the angle of scooping ground materials that flowed into the partition is adjusted or an on-off valve attached to the ground material discharge port is operated from outside the mill.
The sound pressure level in the first chamber is the substitute characteristic for the powder level. A loss of crushing energy can be prevented by judging the sound pressure level and adjusting the flow rate regulator for full coarse grinding in the first chamber.



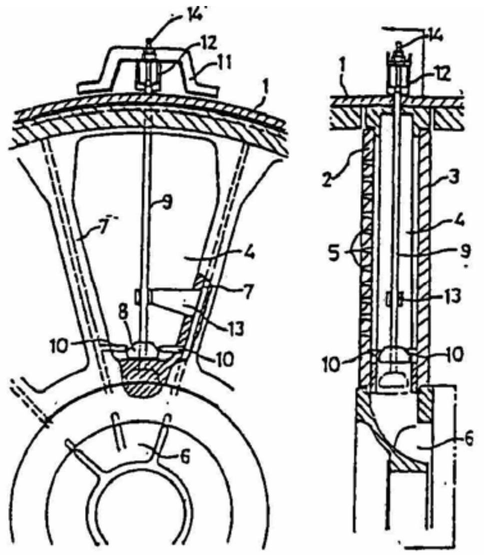


Fig.1 Clinker flow rate regulator (example)
Fig.2 Clinker flow rate regulator (example)</td></tr>
<tr><td>Results</td><td colspan="2">1) The power consumption rate is down 2 to 3 kWh/t.
2) The lives of liners and partition butt straps are extended.
3) The deterioration of coarse grinding efficiency by ball cracks is prevented.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">About 320,000US$ (1000 kW and ∅ 3 m class mill) [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
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Item	Optimization of grinding media	Application Finishing process
Background	To minimize the power consumption rate of a finishing tube mill, the ball size and the mixing and filling factors have been optimized. These years, however, the ball diameter is decreasing as a classification liner and a pre-grinder are adopted. In addition, the lives of such grinding media as balls and back plates are being extended by improving the material (abrasion resistance).	
Descriptions	1) Optimum ball size and mixing ratio For the optimum ball size and ball mixing, Starke, Bond, Paulsen, Bombled, and others have been proposing various calculation formulas from a long time ago. Based on these formulas and empirical rules, mixing has been determined. In recent years, the ball size is decreasing by the adoption of a classification liner and a pre-grinder. (The rate of tube mills using the smallest ball of 17 mm was about 10% in the 1979 survey by Japan Cement Association but increased to 80% in the 1991 survey.) 2) Filling factor of grinding media The filling factor of grinding media greatly affects the grinding capacity and power consumption of a mill. For cement grinding, the optimum value is in the range from 20% to 40% around 30%. To keep the filling factor of grinding media appropriate for high grinding efficiency, appropriate replenishment is necessary for compensating the abrasion of grinding media. Methods of determining media replenishment timing can be classified into five types below. Actually, however, they are used independently or in combination. (1) Load power (2) Blank height measurement (3) Run time (4) Ground tonnage (5) Other (mainly grinding efficiency) The amount of replenishment is determined by the following three elements: (1) Blank height measurement (Ball center measurement) (2) Load (3) Other These elements are used independently or in combination for determination. 3) Improving the material (abrasion resistance) of grinding media Many back plates used to be made of high-magnesium cast steel and many balls used to be made of carbon steel. The recent advance of manufacturing technology is increasing both back plates and balls made of high-chromium cast iron.	
Results	A finishing tube mill can be operated in the optimum status.	
Cost estimation		
Related matters		
Reference		

Item	Improvement of separator	Application Finishing process
Background	With the conventional separator, which has built-in fan, such as "sturtevant-separator", it is difficult to expand the grinding capacity by the scale-up because of lower classification efficiency. Therefore, a new high efficiency separator has been developed.	

Descriptions

The separators are divided into three types according to their structures. The first generation is the built-in fan type, the second is the cyclone air type, and the third is the rotor type.

１）Mechanism

(1) The cyclone air separator comprises the separation section and the cyclones to collect the fine particles. The air circulates by the outside (located) fan. The separation section consists of air vanes and turning blades.

(2) The rotor type separator is the vortex flow type air separator comprised of guide vanes and rotating rotor. The fine particles are collected by a bag filter and cyclones equipped outside the separator housing.

２）Characteristics

(1) The second and third types have lower circulation of the fine particles and higher classification efficiency with more grinding capacity and less specific power consumption. The third type boasts higher classification efficiency with more compact structure.

(2) The second and third types can adjust easily the fineness of products under various operating conditions. The third type can control classifying points in a more wide range just by varying the revolutions per minute.

(3) The products temperature has been decreased as a result of the second and third types introducing much cooler air into the separator. The false set of cement is hard to occur.

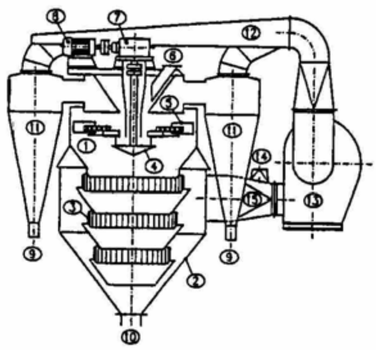
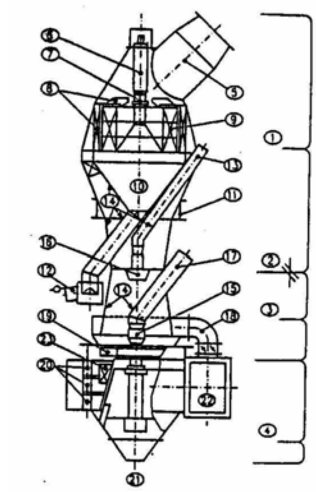


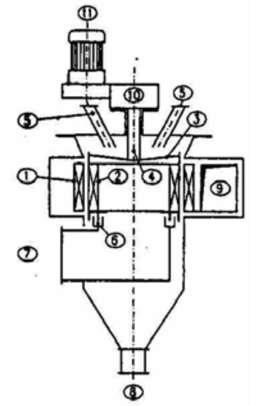
Fig. 1. Cyclone air separator

①separation chamber
② tailings cone
③ air vanes
④ distributor plate
⑤ counterblades
⑥ feed spout
⑦ gearbox
⑧ motor
⑨ fines outlet
⑩ tailings outlet
⑪ cyclones
⑫ air duct to fan
⑬ fan
⑭ dust collecting pipe to filter
⑮ return air duct



① separator part
②optional duct ext. to fit layout
③ desagglamerator
④ grit separator
⑤ fines outlet
⑥ bearling housing
⑦ shaft rotor joint
⑧ guide vane
⑨ rotor blade
⑩ reject cone
⑪ support
⑫ reject outlet valve
⑬ feed inlet
⑭ densit wearcast 2000
⑮ air lock
⑯ spreader plate
⑰ feed from press
⑱ air by-pass
⑲desagglomerator rotor
⑳ guide vane sections
6 outlet to press
7 air inlet
8 rotor blades

Fig. 3. Rotating type separator



① guide vanes
② rotor blades
③ distributor plate
④ rotor shaft
⑤ feed spouts
⑥ sealing
⑦ air + fines outlet
⑧ tailings outlet
⑨ air inlet
⑩ gear box
⑪ motor

Fig. 2. Rotating type

Results	1)Grinding capacity 15% to 25% (Increase) 2)Specific power consumption 10% to 20% (Reduction)
Cost estimation	About 4.5 million US$ for 3,000kW-mill [1US$=¥110]
Related matters	
Reference	

<table>
<tr><td>Item</td><td>Pre-grinding of roll press system</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">To decrease the specific power consumption in finishing process or to increase the output of finish mill, pre-grinding roll crasher, which is installed in the upstream of tube mill, has been introduced since the middle of 1980s.</td></tr>
<tr><td>Descriptions</td><td colspan="2">1) System & Structure
This system increases the output of finish tube mill by installing the pre-grinding roll crusher in upstream of the tube mill.
By passing through the opening between two rolls (a fixed roll and a movable one), materials are crushed by high-pressure(as shown in Fig.1). High-pressure to crush the materials are generated by oil-hydraulics. Abrasion-resistant material is attached on the surface of rolls.
Various kinds of system are available, and the typical one is shown in Fig.2.
2) Operation & Maintenance
(1) Exerting pressures are 50 to 100bars on the basis of the projected area of the roll, onto the layer of clinkers passing between the two rolls.
(2) Abrasion-resistant parts are classified in one unit type or segment type. In any type, abrasion-resistant parts should be replaced to new one or hard facing, if they are worn out.

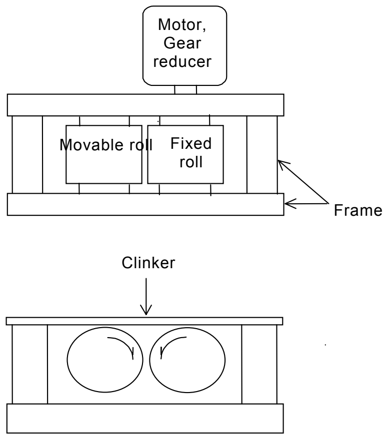


Fig.1 Structure

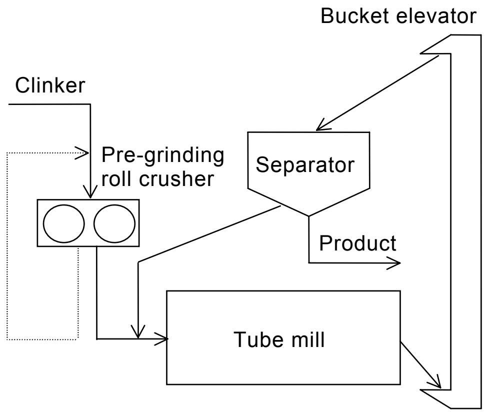


Fig. 2 Flow sheet</td></tr>
<tr><td>Results</td><td colspan="2">1) Grinding capacity of finish mill increases about 30%.
2) Specific power consumption in finishing process decreases about 10%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">The installation cost is about 2.7 million US$ including auxiliary and construction cost, in case of 100t/h output. [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

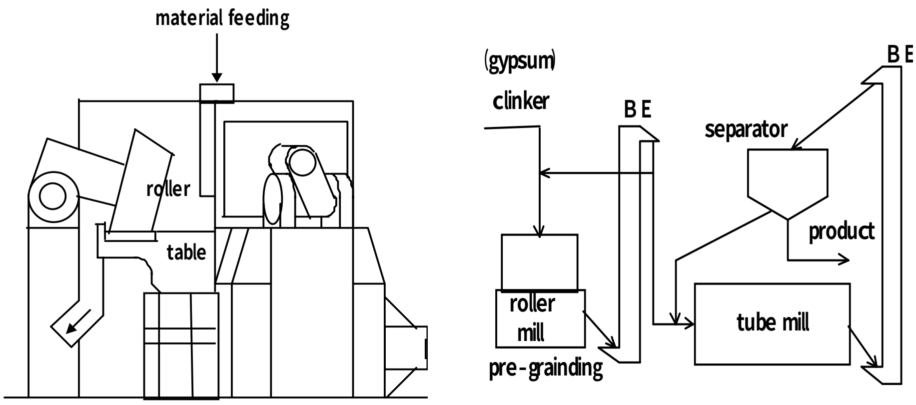
<table>
<tr><td>Item</td><td>Pre-grinding of roller mill system</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">For the purpose of decreasing the specific electrical power consumption in the finishing process, this installs a vertical roller mill for pre-grinding of clinker in the upstream of the tube mill. The roll press system preceded as pre-grinding system, but there are many machinery troubles (flake and crack of roll surface, damage of roll shaft and bearing) for high pressure. This system was developed on the vertical roller mill which has achieve satisfactory results. It was introduced from the latter half of the 1990s, and the introduction rate in 2000 is 13%.</td></tr>
<tr><td>Descriptions</td><td colspan="2">This system installs a vertical roller mill (of high grinding efficiency) for a pre-grinding in the upstream of the tube mill. Clinkers are milled the turn table and 2～4 rollers. The basic structure is the same as vertical roller mills for raw materials or cement. But the roller mill for pre-grinding have no classifier and air sweep. Pre-ground clinkers were discharged outside mill. Fine particles are separated from pre-ground clinkers with vibrating screen, and they are fed to finishing tube mill.
The structure (Fig.1) and the flow (Fig.2) are shown below.


Fig.1 Structure
Fig.2 Flow</td></tr>
<tr><td>Results</td><td colspan="2">1) rinding capacity of finish mill increases about 30~60%.
2) Specific power consumption in finishing process decreases 10~20%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">6.4~9.1 million US$ including cost of ancillary facilities and construction [100t/h] [1US$=¥110]</td></tr>
<tr><td>Related materials</td><td colspan="2">1) Raw material pre-grinding roll crusher</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Item</td><td>Automatic run control of tube mill</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">Only several percent of the power consumption for a tube mill is used effectively and most of the energy is dissipated as heat or sound. Therefore, raising the grinding efficiency of the mill is very important for reducing the power consumption rate. To raise the efficiency, the filling factor of grinding media and materials to be crushed in the mill should be kept optimum. For this control, the power of the bucket elevator at the mill outlet used to be kept constant. This control method, however, has a disadvantage of reverse operation in case that the mill should be clogged. To compensate for this disadvantage, mill acoustic control and mill vibration control have been adopted. In addition, fuzzy control was also developed and implemented.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The filling factor in a mill is kept constant by the following automatic control:

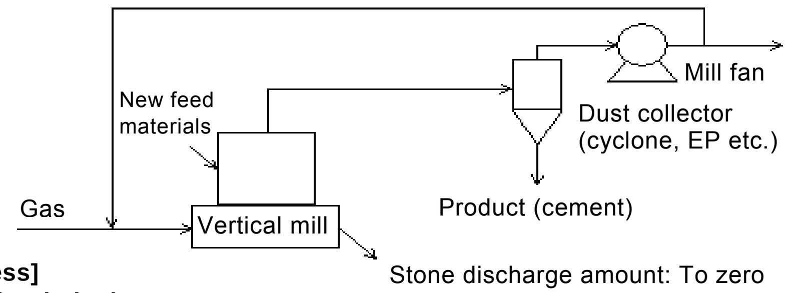
1) Power (current) control of the bucket elevator at the outlet of the mill
The power of the elevator at the outlet of the mill is detected and the mill supply rate is adjusted to achieve the target power value. This method became popular at the earliest. This control has a disadvantage of reverse operation that the elevator power decreases and the supply amount increases when the slit clogging of the butt strap in the mill progresses. In this case, slit clogging must be monitored by the air flow rate through the mill. As of Year 2000, this control is adopted by about 70% of the finishing tube mills in Japan.

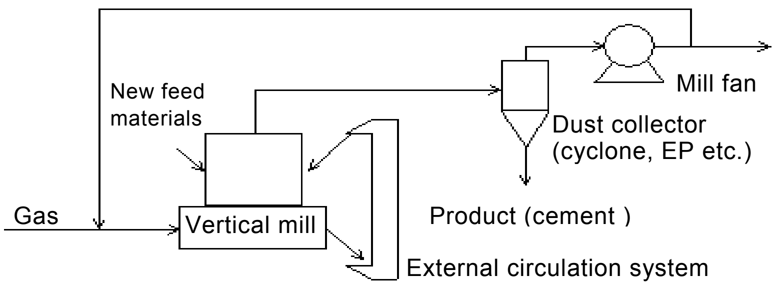
2) Mill acoustic control
This control uses the fact that the grinding sound in a mill changes with the filling factor of ground materials in the mill. The grinding sound in the first chamber is picked up by a microphone and the supply amount is controlled by the pitch of the sound. When several mills are running adjacently at the same time, it is difficult to detect the grinding sound. This control is adopted by about 10% of the mills in Japan.

3) Mill vibration control
This control uses the fact that the vibration of the large metal of a mill changes with the filling factor of ground materials in the mill. It is comparatively difficult to receive the influence of adjacent mills simultaneously running. As of Year 2000, the adoption ratio in Japan is less than 10%. According to the result of a survey by the Committee, the operators are very satisfied with the control performance.
Fuzzy control automatically optimizes the filling factor in a mill.

4) Fuzzy control
Based on the mill acoustic level, elevator power, mill differential pressure, and some more process data, fuzzy inference from present rules is conducted on changes of mill grinding conditions by a computer. Then the target value of filling factor in the mill is optimized to improve the grinding efficiency. Experiences and techniques are needed to set the rules. Once the rules have been set appropriately, efficient run is possible. As of Year 2000, this control is adopted by less than 10% of the mills in Japan.</td></tr>
<tr><td>Results</td><td colspan="2">1) The power consumption rate is down about 2 to 10%.
2) The labor for running operation can be reduced.
3) The quality becomes stable because of stable run.</td></tr>
<tr><td>Cost estimation</td><td colspan="2"></td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Vertical roller mill for cement grinding	Application Finishing process
Background	In the cement grinding process, grinding system using the tube mill is widely applied for long year. Recently, especially from 1980s, grinding system using the vertical roller mill, which has effective grinding performance, is developed and applied in the cement grinding process.	
Descriptions	Basic equipment structure of the vertical roller mill for cement grinding is the same as the vertical roller mill of raw material and coal grindings. The materials such as clinker and gypsum fed into the mill are ground by compression and shearing forces between the grinding table and two or four rollers, which are hydraulically loaded and controlled. Ground cement materials are sent to separator installed in mill upper position by air and classified to coarse particles and fine product. Coarse particles are returned on the grinding table to re-ground and the fine product is sent to dust collectors such as cyclone and/or bag filter. The advantage of the vertical roller mill for cement (comparison with the tube mill) 1) Highly efficient grinding is possible with considerably low electrical power consumption. 2) The residence time of cement grinding in the vertical roller mill is much shorter than that of tube mill. Since system operational control response is superior, quality management on the cement product is easy. 3) Therefore the vertical roller mill for cement produces little heat for grinding, and quality trouble due to the excessive rise of temperature of cement is less likely to occur. 4) The installation area of the vertical roller mill is about half of tube mill grinding system. But the introduction of a pre-grinding grinder has become mainstream in Japan, and the above-mentioned technology is spreading mainly overseas.	
Results	Electrical power consumption can be reduced by 30 % (compared with the tube mills).	
Cost estimation		
Related matters	External circulating system to vertical roller mill for cement.	
Reference		

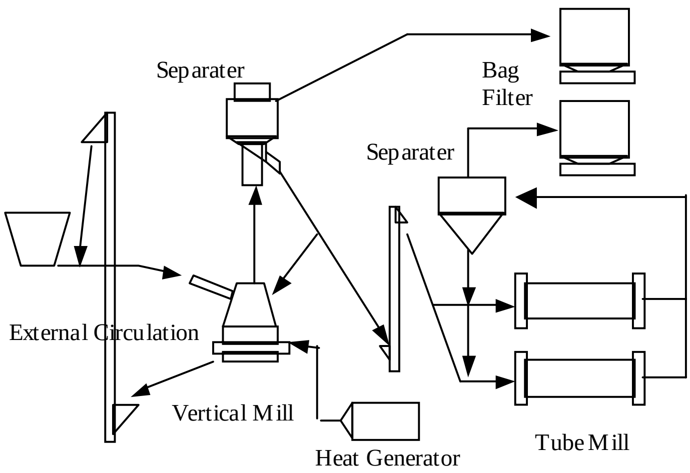
<table>
<tr><td>Item</td><td>External materials circulating system to cement grinding vertical mill</td><td>Application
Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">In the cement grinding process, the vertical roller mill having high grinding performance is applied especially cement grinding instead of the conventional tube mill. For further power saving, external material circulating system is adopted as same as raw material grinding process.</td></tr>
<tr><td>Descriptions</td><td colspan="2">As described in Page 2 of External Circulating System to Vertical Roller Mill, the external circulating system is adopted to vertical roller mill grinding process in order to reduce power consumption of mill fan. As explained in it, uncrushed large size materials jumped out from table of the mill fall through gas inlet box and collected by the external circulating system installed below the mill. And then they are re-transported to fresh material feed equipment to re-send the mill. Since the uncrushed raw materials are not blown-up by the gas, transportation energy of the gas, which is generated by mill fan, extremely decreases.
In the conventional roller mill system, in which the proposed external material circulation system is not installed, the power consumption by the mill fan occupies 60% of the system because high speed gas flow is blown at the around of the table to prevent falling of uncrushed larger material jumped out from the table.
To the contrary, vertical roller mill having external circulating system does not require the high and large gas flow because the uncrushed materials can fall from the table to it and be re-sent to mill.
As the result, gas flow rate is reduced about 30%, pressure loss is also reduced about 30% and power consumption of the mill fan reduces about 50%.
The external circulation ratio (=external circulation material flow / new feed material flow) is about 50 to 100%
[Conventional process]


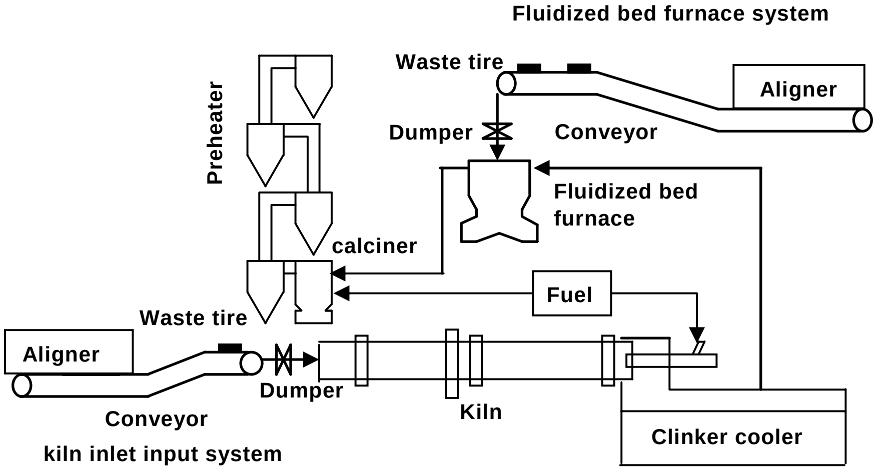
[New process]
(External circulation)

</td></tr>
<tr><td>Results</td><td colspan="2">Specific power consumption is down about 10%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">System with a grinding capacity of about 100 t/h (including the incidental facilities and construction expenses): About 730 thousand US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">External circulating system to vertical roller mill / Raw material process</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

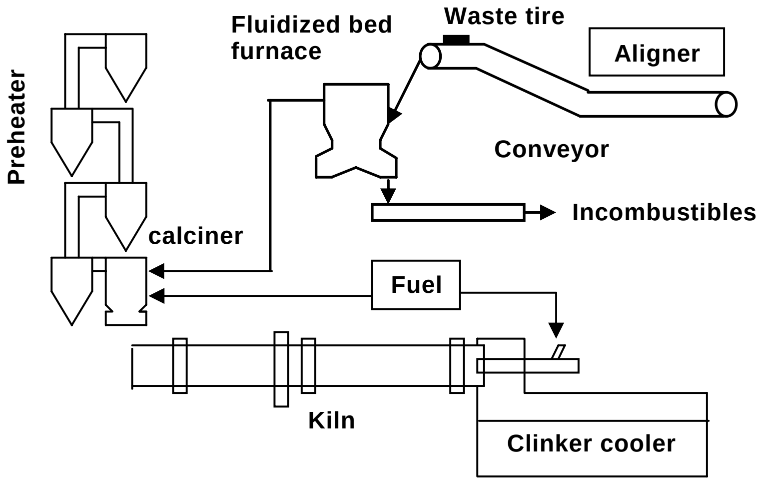
<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Automatic control
of cement grain size</td><td>Application</td></tr>
<tr><td>Finishing process</td></tr>
<tr><td>Background</td><td colspan="2">The grain size management of cement as the final product is important for maintaining stable quality and efficient run. When an finishing mill is in actual operation, however, the cement grain size changes with the passage of time under the influence of many factors. Therefore, a technology was developed and implemented to adjust the separator automatically.</td></tr>
<tr><td>Descriptions</td><td colspan="2">In finish grinding, the grain size of refined powder (product) changes with the passage of time under the influence of various factors even when the running conditions are fixed.
These factors are as follows:

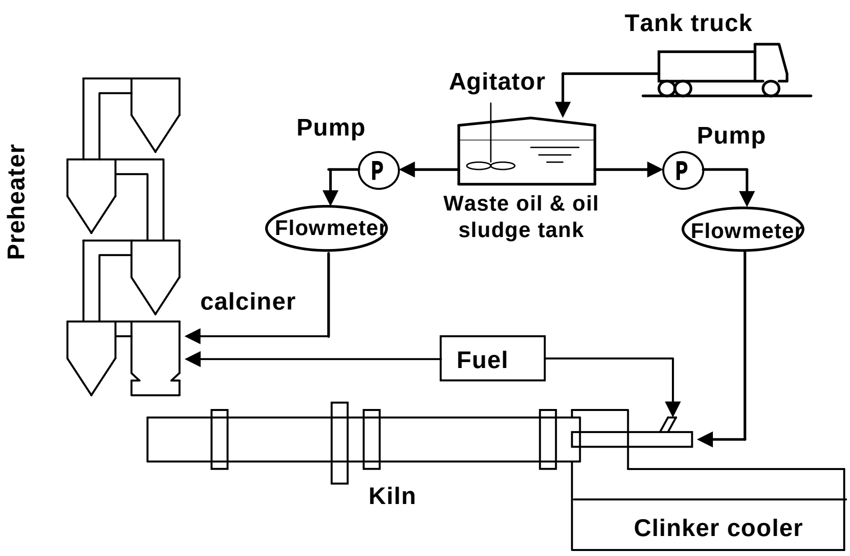
(1) Crushability of clinker
(2) Grain size and temperature of clinker
(3) Type and addition rate of plaster and mixture

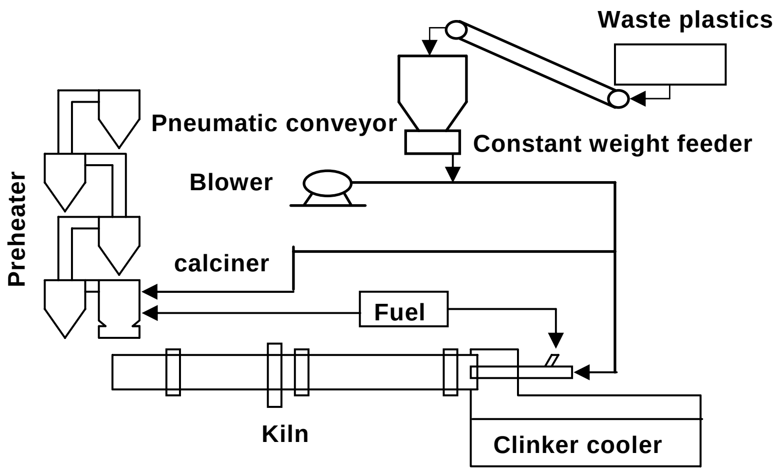
Of these factors, a change of the clinker properties cannot be avoided to some extent as a main factor if the conditions of ground materials and facilities are considered. A means was expected to stabilize the grain size by absorbing the influence.
For finish grinding, the mill run is often intermittent. The early stabilization of refined powder grain size after mill activation is another subject to solve for maintaining the stable quality and making the run efficient.
Refined powder is automatically sampled and measured by a grain size distribution measuring device of the laser diffraction type. Then the separator blade or rotor rotation speed is automatically adjusted so that the measured value will match the target.</td></tr>
<tr><td>Results</td><td colspan="2">1) The cement quality (grain size) is stable.
2) The power consumption rate is down 3 to 5%.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">About 364,000US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

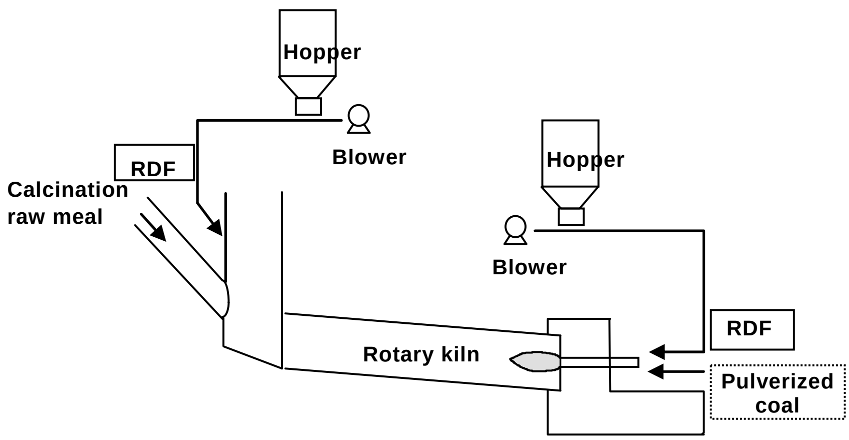
Item	High efficiency grinding of blast furnace slag	Application: Finishing process
Background	In the past, slag grinding is performed in a tube mill with dryer. This requires relatively higher power consumptions, and efficiency improvement in this process has become a great concern. Improvements in slag grinding efficiency was developed and implemented with existing cement manufacturing technology.	
Descriptions	Improvements in the grinding process to produce fine granulated blast furnace slag suitable for use in the production of blast furnace cement was achieved with pre-grinding and vertical mill technologies used in cement manufacturing. 1. The installation of vertical mill In a vertical coal mill, drying, grinding, and separating/classifying of ground material are done simultaneously. The hot air used for drying is supplied with a hot wind generator. Slag contains iron grain, which could damage the rotating table and aggravate grinding efficiency. Hence, the removal of these iron grains before commencing the grinding process, using an external circulation system with a magnetic-separator device, is crucial. 2. The installation of pre-grinding equipment There are cases where a vertical mill is installed to the existing tube mill to enhance grinding efficiency while reducing power consumption. With the use of vertical mill, pre-grinding and cement grinding processes are performed separately. Reduction in the size of grinding media used in the tube mill is expected to improve grinding efficiency. However this would partially ruin overall efficiency improvement level.  **Fig. The example of the combination of tube mills and vertical mill**	
Results	Reduction in unit electricity consumption (Blended value 4,000cm^2/g) * Tube mill 70kWh/t (approx., excluding drying) * Vertical mill <40kWh/t (including separator, wind-chamber/fan, conveyor systems, and etc)	
Cost estimation	About 7.3 million US$ including cost of supplemental facilities and construction fees [40t/h] [1US$=¥110]	
Related matters	Introduction of vertical raw material mill, vertical cement mill, vertical coal mill.	
Reference		

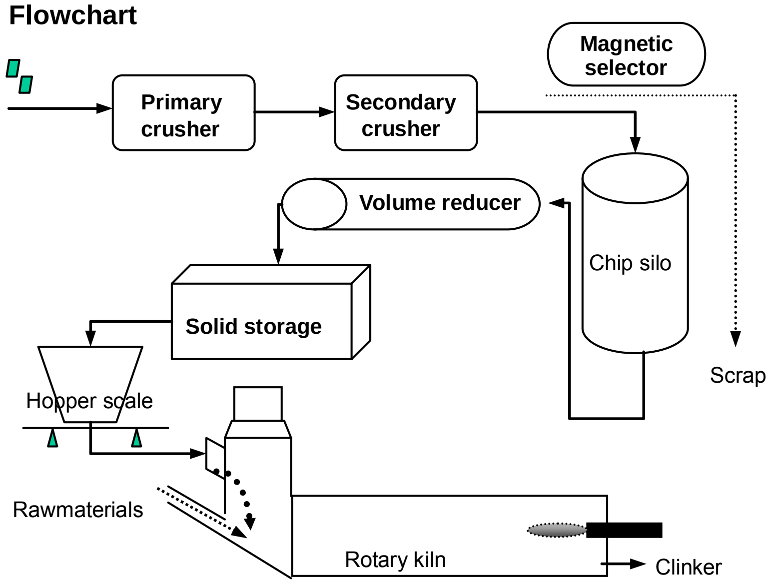
Item	Automatic input facilities for waste tires	Application: Use of Alternative Fuels and Raw materials <AFR>
Background	Waste tires used to cause illegal disposal and other social problems because their recycling by tire manufacturers or effective use as a fuel could not catch up with the growth. The cement industries in Japan tackled this problem early and has been using waste tires as a substitute fuel since about 1980.	
Descriptions	1) After used tires from passenger cars, trucks, and buses are cut or kept them on a shelf as they are, they are put into a kiln inlet (kiln bottom) to use them as a heat source for burning clinkers. 2) The tire input facilities generally consist of an aligner to automatically align tires and a conveyor to transport the aligned tires to the kiln inlet. A specified number of tires are input at fixed intervals. 3) In addition, waste tires may be processed with a fluidized bed furnace in the middle of an air bleed duct to heat the secondary air (air recovered from the clinker cooler) for calcinery. **Fig.** shows a waste tire processing flow by the kiln inlet input system and the fluidized bed furnace system.  **Fig. Waste tire processing flow**	
Results	The effective heat from waste tires is about 25 to 29 MJ/kg (6,000 to 7,000 kcal/kg). Fossil fuels for the same amount of heat can be saved.	
Cost estimation	System for 10,000 t/year: About 2.7 million US$ [1US$=¥110]	
Related matters	Waste tire gasification facilities	
Reference		

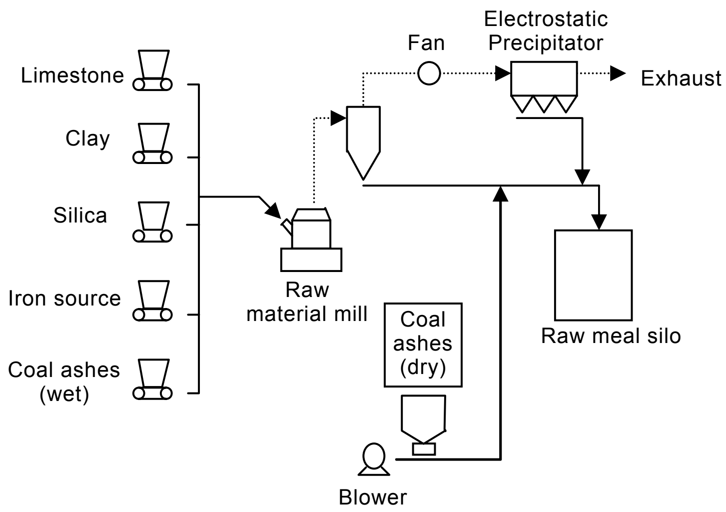
Item	Waste tire gasification facilities	Application Use of AFR
Background	Waste tires used to cause illegal disposal and other social problems because their recycling by tire manufacturers or effective use as a fuel could not catch up with the growth. The cement industry tackled this problem early and has been using waste tires as a substitute fuel since about 1980s. The conventional method of putting waste tires into a kiln as they are, however, has a quantitative limit depending on the kiln size. The gasification technology was developed to increase the capacity and improve the heat energy efficiency.	
Descriptions	1) Used tires from passenger cars, trucks, and buses are put into a gasification furnace as they are or after cutting. The tires are heated in a reducing atmosphere and gas produced by their thermal decomposition is led into a calciner for effective use as a substitute fuel. 2) Steel and other incombustibles are discharged from the gasification furnace and eliminated from the system. This solves such problems as non-uniform components attributable to the mixing of much steel. 3) There are several types of gasification furnaces, such as the fluidized bed type and the kiln type. **Fig.** shows a flow of waste tire gasification flow by a fluidized bed furnace.  **Fig. Waste tire gasification flow**	
Results	The heat energy from waste tires is about 25 to 29 MJ/kg (6,000 to 7,000 kcal/kg). Fossil fuels for the same amount of heat energy can be saved.	
Cost estimation	System for 7,000 t/year: About 1.8 million US$ [1US$=¥110]	
Related matters	Automatic waste tire input facilities	
Reference		

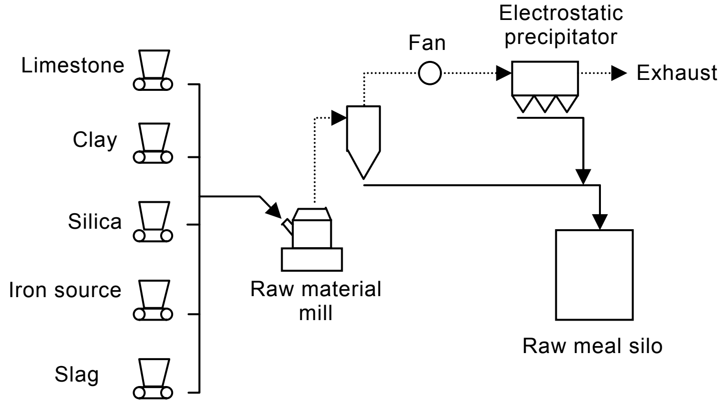
Item	Waste oil and oil sludge input facilities	Application: Use of AFR
Background	Waste oil and oil sludge used to be left oil drums or incinerated. As the future shortage of fossil fuels is anticipated, waste oil and oil sludge utilization technologies have been developed and implemented since about 1985 in Japan, as part of energy conservation activities.	
Descriptions	1) After waste oil and oil sludge brought in by oil drums or tank trucks are stored in a tank, they are put into a kiln or calciner by a pump for effective use as a heat energy for burning clinkers. 2) Flowmeters are installed on oil & oil sludge transportation pipes for the remote adjustment of flow to a set rate by controlling the pump rotation speed. **Fig.** shows a flow on a waste oil & oil sludge processing flow by calciner or kiln.  **Fig. Waste oil and oil sludge processing flow**	
Results	Waste oil and oil sludge vary greatly in quantity but can produce heat energy of about 10 MJ/kg (several 1,000 kcal/kg). Fossil fuels for the same amount of heat energy can be saved.	
Cost estimation	Storage and processing facilities for about 10,000 kl/year: About 727 thousand US$ [1US$=¥110]	
Related matters		
Reference		

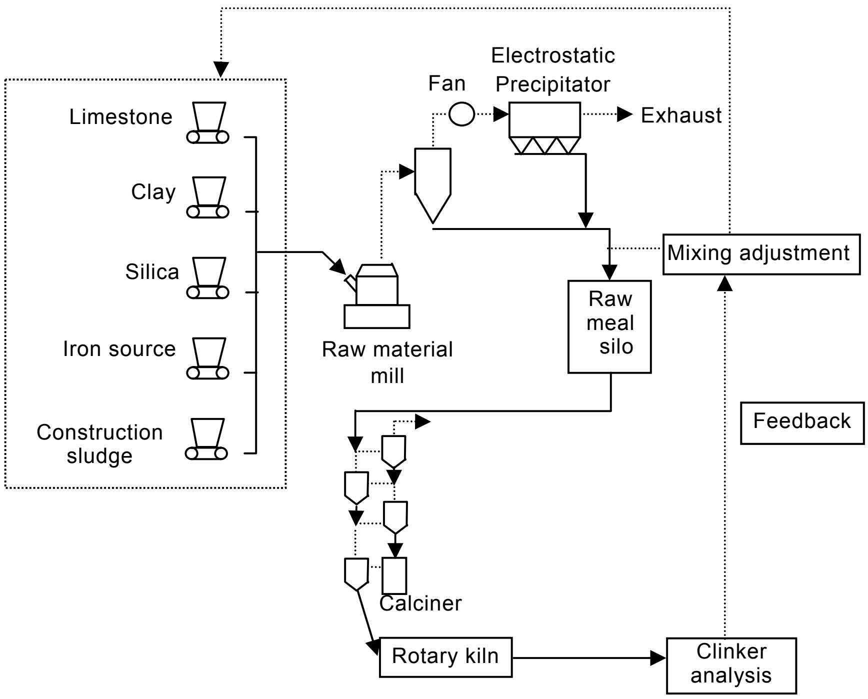
Item	Waste plastic processing facilities	Application Use of AFR
Background	Waste plastics generally used to be reclaimed on final disposal sites. Since it is difficult to secure final disposal sites and the shortage of fossil fuels is anticipated, waste plastic utilization technologies are being developed as part of resources and energy conservation activities.	
Descriptions	The waste plastic processing technologies recently developed and now in use are mainly to shred waste plastics until almost the same combustion characteristics as the main fuels can be obtained. 1) After foreign matter is removed, waste plastics are shred into pieces of 10 to 20 mm. Then the shreded plastics are fed to a kiln or calciner quantitatively rate for effective use as an alternative fuel. 2) A constant weigh feeder allows the remote adjustment of weighing or rotation speed. For transportation, a roots blower is used as the pneumatic conveyor. **Fig.** shows a waste plastic processing flow.  **Fig. Waste plastic processing flow**	
Results	There are various kinds of waste plastics. The effective heat from waste plastics is about 17 to 42 MJ/kg (4,000 to 10,000 kcal/kg). Fossil fuels for the same amount of heat can be saved.	
Cost estimation	System for about 10,000 t/year (including shredding facilities): About 3.6 million US$ [1US$=¥110]	
Related matters		
Reference		

Item	RDF processing facilities	Application Use of AFR
Background	Waste used to be incinerated or reduced in volume and then reclaimed on final disposal sites. Since the emission of dioxins from incinerators and the securing of final landfill sites are posing problems, however, it is expected to reduce and recycle waste. As a method of recycling, general garbage and industrial wastes are being solidified as RDF for use as a fuel (RDF: Refuse Derived Fuel). RDF processing is effective at cement plants where incinerated ashes are available as raw materials.	
Descriptions	1) Burnable waste sorted and collected by local governments is crushed, sorted, dried, and molded into RDF of 10 to 30 mm in diameter and 20 to 50 mm in length for easy storage and transportability. 2) RDF carried to a cement plant is put into a kiln bottom or mouth by pneumatic transportation facilities to use effectively as a heat energy for burning clinkers. 3) This saves fossil fuels of the amount for heat energy. Incinerated ashes require no separate processing because they are used as part of the raw materials. 4) In addition, no dioxins are generated because of long stay at a high temperature in a cement kiln. 	
Results	RDF produces heat of 15,000 to 20,000 kJ/kg (3,500 to 4,500kcal/kg). RDF use of 10 t/d reduces coal consumption by about 5 t/d.	
Cost estimation	Facilities for accepting and processing 10 t/d (excluding chlorine bypass facilities): 646 thousand US$ [1US$=¥110]	
Related matters	Cyclone clogging prevention technology	
Reference		

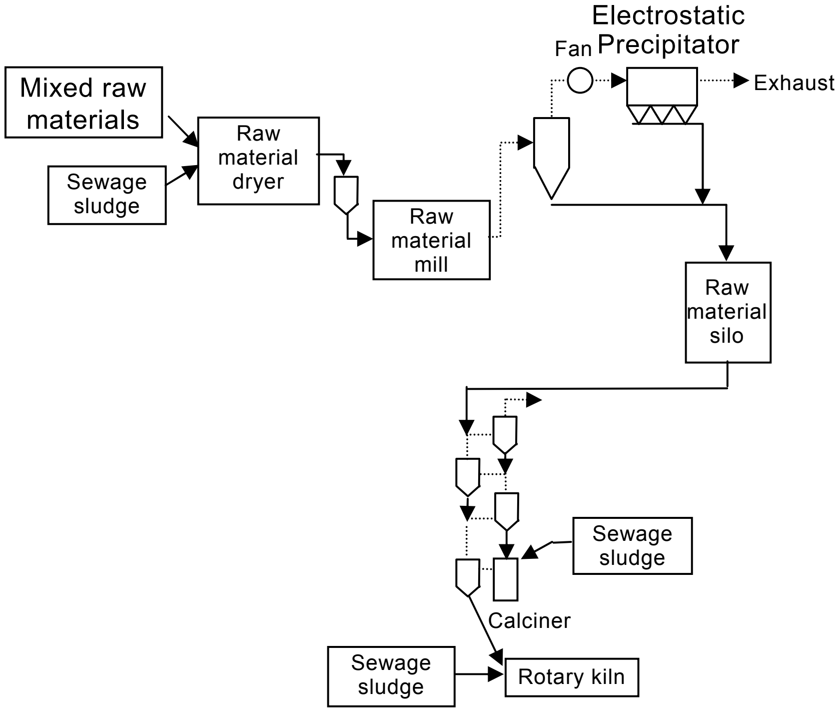
Item	Recycling of “pachinko machine”	Application Use of AFR
Background	In Japan, it is estimated that pachinko machines (Japanese pinball machine) are produced about 2.2 million units every year and are disposed as the same. The establishment of technologies for optimum processing and recycling has been expected because illegal disposal and large field heaping posed social problems.	
Descriptions	“Pachinko,” a machine for entertainment, consists of electronic parts and also metallic, plastic, and wooden sections and is difficult to handle at a later process if merely crushed for recycling. Therefore, a comprehensive processing system is constructed for complete recycling. This system consists of the following processes: 1) Recovery of LCD and other recyclable electronic parts and their return to manufacturers 2) Sorting and recovery of iron parts by magnetic force and their sale as scraps 3) Manufacture of solid fuels mainly from plastic and wooden materials 4) Fixed-quantity feed to and processing in cement kiln For solid fuel production, a volume reducer by compressive extrusion is used. Plastics molten by friction heat work as adhesives for molding and solidification. The solid fuel size is about 100 mm in diameter and 150 mm in length (about 2 kg/piece). **Flowchart**  	
Results	1) Slid fuel: 15 kg/unit Heat: 27 MJ/kg (6,500 kcal/kg) 2) Substitute of coal fuel	
Cost estimation	1) System for processing 400,000 units/year: About 8.2 million US$ [1US$=¥110]	
Related matters		
Reference		

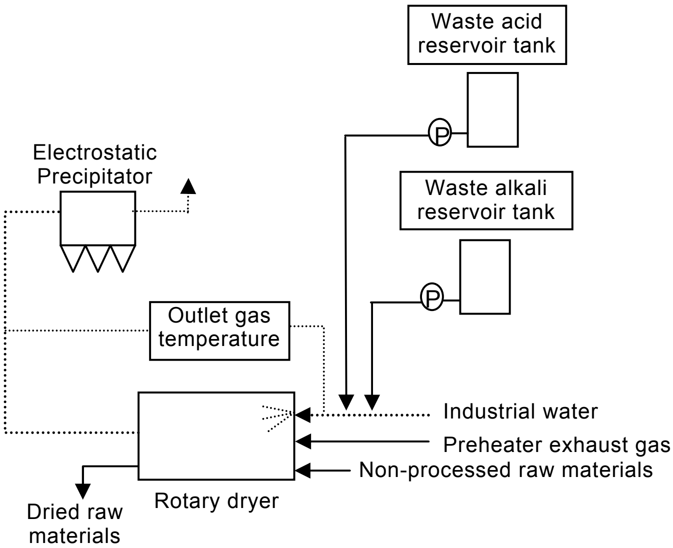
Item	Substitute raw material processing technology (Coal ashes)	**Application** **Use of AFR**
Background	Coal ashes recovered by dust collectors at pulverized coal combustion boilers are discharged a lot mainly from thermal power plants throughout the nation and predicted to further increase in future. Although various processing methods are now under aggressive study, further utilization at cement plans is expected because it is difficult to process large quantities and to secure disposal sites.	
Descriptions	1) Coal ashes are mainly made of silica (SiO_2) and alumina (Al_2O_3) and used as a substitute for natural raw materials of cement. 2) According to the properties, coal ashes are put into a system at the stage of mixing non-processed raw materials or after the stage of grinding raw materials as part of mixed raw materials. 3) Coal ashes containing carbons not burnt help saving fossil fuels because their combustion heat is available as a heat source for burning clinkers. If coal ashes are used in large quantities, however, the heat balance may be lost. 4) Coal ashes are already used at many cement plants and the unit consumption is about 10 to 100 kg/t-cl. 	
Results	1) Natural raw materials (mainly clay) can be saved. 2) Fossil fuels can be saved by carbons not burnt (hundreds to thousands kJ/kg).	
Cost estimation	2000 ton-silo and input facillities: 2.7 to 3.2 million US$ [1US$=¥110]	
Related matters		
Reference		

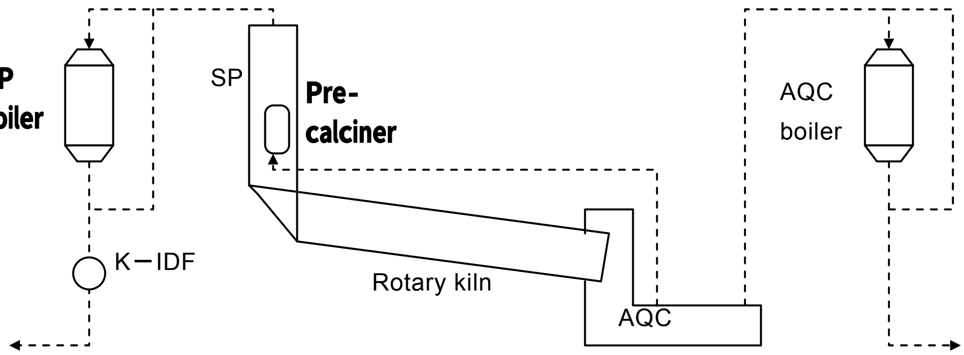
Item	Substitute raw material processing technology (Slag)	Application Use of AFR
Background	At the process of manufacturing iron & steel or nonferrous metals, a product of reaction between impurties in raw materials and limestone added as an agent to eliminate sulfur and impurities is discharged as a molten oxide. The oxide is cooled and crushed. This is called slag and discharged a lot throughout the nation. From a long time ago, slag has been used as cement raw materials and also road construction materials.	
Descriptions	As a representative slag having a hydraulic property, blast furnace slag is ground to fine particles, mixed with cement, and used widely as blast furnace cement. On the other hand, various kinds of slag lower in quality are used as raw materials for cement. 1) Blast furnace slag and convertor slag from iron & steel manufacturing and slag from non-ferrous metal manufacturing are used as substitutes for cement raw materials. 2) As one of raw materials, slag is used at the stage of mixing non-processed raw materials. The maximum consumption is about 250 kg/t-cl. 3) Slag contains CaO about 40 to 45%. Unlike limestone, however, decompositionheat is not necessary because decarboxylation reaction is already completed. The heat consumption rate is reduced corresponding to the amount of use.  	
Results	1) When slag of 10kg/t-cl is used, the heat consumption rate is reduced by about 17 kJ/kg-cl (4kcal/kg-cl). 2) As the generated carbon dioxide decreases, the fan power consumption is also reduced slightly.	
Cost estimation		
Related matters		
Reference		

Item	Substitute raw material processing technology (Sludge)	Application: Use of AFR
Background	A large amount of construction sludge generated throughout the nation used to be reclaimed for final disposal. With the decrease of land for reclamation, illegal disposal increased. Since it is also difficult to secure disposal sites, an effective utilization technolgy is expected.	
Descriptions	1) Construction sludge containing a certain amount of water or more is used at the stage of mixing non-processed raw materials. Construction sludge not containing so much water is supplied before the grinding of raw materials as a substitute for cement raw materials. 2) Construction sludge has various properties and components. The sludge is preprocessed when difficult to use as it is. 3) Construction sludge containing much water is used after handling is improved by filter press or mixing with other dry raw materials. 	
Results	1) The use of natural raw materials is reduced. 2) The service life of final disposal site is extended.	
Cost estimation	The use of existing facilities cuts costs. Unchoking measures : hundreds of thousands to million of US$	
Related matters	Automation of raw material mixing control	
Reference		

<table>
<tr><td>Item</td><td>Substitute raw material processing technology (Sewage sludge)</td><td>Application
Use of AFR</td></tr>
<tr><td>Background</td><td colspan="2">Sewage sludge from local governments throughout the nation used to be disposed of mainly by reclamation or sea dumping.
The sea dumping of industrial wastes is becoming a social problem and their effective utilization is expected.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Sludge from sewage plants is brought to cement plants in the form of dehydrated cake (water content: about 80%) or incinerated ashes.

1) Incinerated ashes are mixed as a substitute for raw materials at the stage of mixing raw materials.
2) Because of the smell and difficult handling, dehydrated cake is directly put from the pressure feed pump into the furnace (rotary kiln or calciner).
3) The cake contains burnable organic substances. Because of high water content, however, the cake is thermally offset and used as a substitute for raw materials.

</td></tr>
<tr><td>Results</td><td colspan="2">1) The consumption of natural resources is reduced.
2) The service life of final disposal site is extended.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">Pressure feed pump into the furnace : 1.8 to 3.6 million US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Automation of raw material mixing control</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Waste acid and alkali processing facilities	Application: Use of AFR
Background	The general method of disposing of waste acids and alkalis in large quantities used to be sea dumping after neutralization. Since sea dumping is now prohibited by the London Dumping Convention, a safe and effective processing method is expected.	
Descriptions	1) Combustion exhaust gas discharged from a preheater is used effectively for drying and then its dust is collected by an electrostatic precipitator. To optimize the conditions of dust collection, industrial water is sprayed to adjust the temperature and humidity of exhaust gas. 2) Instead of this industrial water, waste acid and alkali solutions are used to evaporate the water content occupying a great percentage of waste liquid. 3) There is a comprehensive recovery system for treating waste liquid from liquor brewery and photographic development easy to collect and transport.  	
Results	The consumption of water resources and the energy for waste water treatment can be reduced.	
Cost estimation	Receiving and spray facilities : several hundreds of thousand US$	
Related matters	Chlorine bypass system	
Reference		

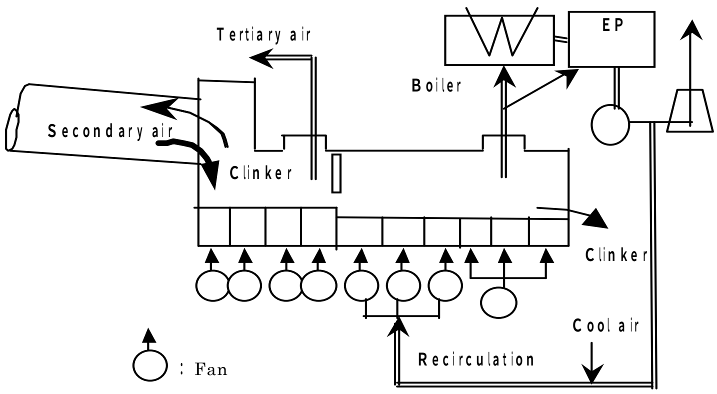
Item	Power generation utilizing waste heat	Application: Waste heat recovery
Background	The temperature of the exhaust from the suspension preheater (SP) or the new suspension preheater (NSP) is about 400℃. The exhaust has the surplus heat even if it is used to dry the raw materials. Also the surplus heat comes from the clinker cooler. It was desired to utilize the surplus heat (= waste heat) for energy saving.	
Descriptions	The power generator by the waste heat has been installed with the progress of technologies on the waste heat generation and after the appearance of large-scale kilns. The popular system is as follows. The boilers are installed at the outlet of suspension preheater or clinker cooler. The low pressure steam is made in boiler by waste heat recovery. And, the electrical power is generated with the steam turbine. The amount of generated electrical power per 1 ton of clinker is 35-40kW on an average. In the case of kiln of 5000 ton per 1 day, the 8000kW of electrical power are generated. In the typical NSP kiln equipped with power station by waste heat, the energy utilization efficiency on the burning process reaches about 80% and the temperature of the exhaust after using of drying raw materials is about 100℃. 	
Results	The power station by waste heat can generate electrical power of about 35 to 40 kW per 1 ton of clinker.	
Cost estimation	About 27.3 million US$ including cost of supplemental facilities [1US$=¥110]	
Related materials	The recycled utilization of the exhaust gas of the clinker cooler	
Reference		

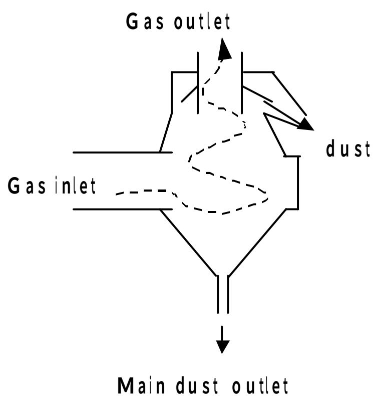
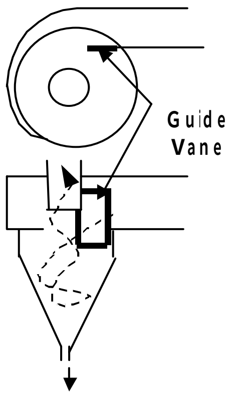
<table>
<tr><td rowspan="2">Item</td><td rowspan="2">Recirculation of exhaust air from cooler</td><td>Application</td></tr>
<tr><td>Waste heat recovery</td></tr>
<tr><td>Background</td><td colspan="2">A clinker cooler exhausts air of about 200 to 300°C. This exhaust air used to be released into the atmosphere as it is. Installing a waste heat boiler is an effective means of using potential heat from the exhaust air. However, means of thorough energy conservation are expected.</td></tr>
<tr><td>Descriptions</td><td colspan="2">Regarding a cooler, it is most important to improve the recovery of heat to the secondary air for combustion. From the viewpoint of an whole kiln, it is also important to thoroughly make an effective use of residual heat not having a very great value as heat.

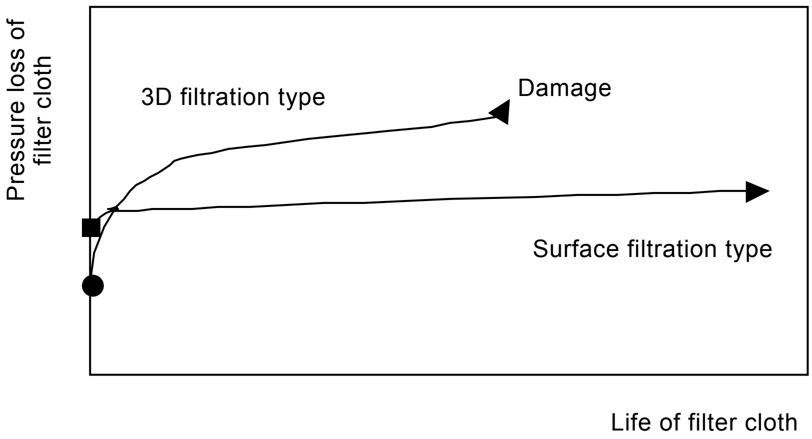
From air discharged out of a cooler, dust is removed by an electrostatic precipitator or bag filter. Then the low-temperature air is circulated again to cool clinkers. This cooler exhaust recirculation technology minimizes heat discharge out of the system by using potential heat effectively.

(a) If a waste heat boiler is installed on a cooler, exhaust air of about 100°C at the boiler outlet is led again to the fan for the rear stage of the cooler to increase heat recovery at the boiler. The cooler exhaust of a great heat value increases the recovery efficiency at the boiler.

(b) In a grate-type cooler, low-temperature exhaust air is led again to the fan for the front stage of the cooler to get the high-tempetrature secondary air for burning.

Example : With waste heat boiler

</td></tr>
<tr><td>Results</td><td colspan="2">1) (a): Waste heat recovery rate up about 10% (50% of exhaust air circulated)
2) (b): Heat consumption rate down about 25 kJ/kg-cl (6 kcal/kg)</td></tr>
<tr><td>Cost estimation</td><td colspan="2">0.9 to 1.4 million US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2">Power generation from waste heat</td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>

Item	Reduction of cyclone pressure loss	Application: Common
Background	The power consumption rate of an exhaust fan at a preheater is affected by cyclone pressure loss. If the negative pressure is great, leakage air increases. Therefore, a cyclone of low pressure loss was expected.	
Descriptions	A cyclone pressure loss is reduced by the following technologies: 1) Adopting a cyclone of a special shape The inlet shape of an ordinary cyclone is devised to reduce the inlet wind velocity. This exhibits the gravity sedimentation effect and reduces the pressure loss while maintaining the dust collection efficiency. Such special types as axial and horizontal are also available. 2) Installing a guide vane A vane is installed where the inlet gas flow collides against the swirling gas flow. This prevents the inlet gas flow from diminishing and assists the formation of a downward flow in the cyclone to reduce the pressure loss while maintaining the dust collection efficiency. 3) Devising the cylinder in the cyclone By considering the applicable cyclone position, the internal cylinder and the length of the rectifier plate in the cylinder are adjusted. According to a report, the pressure loss at inversion can also be reduced greatly by installing a special device at the lower part of the internal cylinder.  Special cyclone  Guide vane	
Results	1) Guide vane type: Pressure loss down 5 to 10% (equivalent dust collection efficiency) 2) Special cyclone: Pressure loss down 30 to 40% (equivalent dust collection efficiency)	
Cost estimation	1) About 9,000 to 14,000US$ [1US$=¥110] 2) About 55,000US$ [1US$=¥110] (straight body of 4,000 mm in diameter × 2 + duct alteration)	
Related matters	Five-stage preheater	
Reference		

Item	Reduction of bag filter pressure loss	Application: Common
Background	The conventional bag filter has disadvantages that the pressure loss and power consumption rate increase with the passage of time as the filter cloth deteriorates and that the filter cloth is damaged in a short period. Therefore, a filter cloth of a low pressure loss was expected to support stable run for a long period.	
Descriptions	The conventional bag filter uses a felt cloth for filtration. This cloth is for three-dimensional filtration where the primary dust layer formed on the surface of the cloth filters later dust. Therefore, dust penetrates into the material and increases the pressure loss with the passage of time. To solve this disadvantage, a new filter cloth was developed by laminating a fine multipore film on the surface of a felt substrate. Since this is surface filtration by micropores, dust comes off easily from the filter cloth. By shaking off dust appropriately, the pressure loss of the filter cloth can be kept almost constant. Compared with the felt filter cloth, the filter cloth has a slightly great pressure cloth at the beginning of use but is almost free of influence by residual dust. Therefore, the new filter cloth can be used stably for a long time with a low pressure loss.  **Life of filter cloth and pressure loss**	
Results	1) The pressure loss is down about 30%. (Electric power down or processing wind rate up) 2) The maintenance frequency is reduced. 3) The bag filter can be used for a long period at a stable wind rate. 4) The filter cloth has a twice or longer life.	
Cost estimation	150 mm dia. × 3,500 mm long: About 450US$ [1US$=¥110]	
Related matters		
Reference		

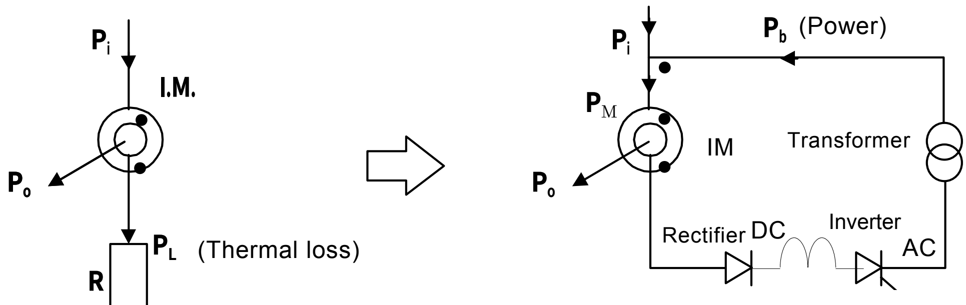
Item	Fan rotation control	Application: Common

Background

At the cement manufacturing process, many large fans are used. Power consumption by these fans is regulated by throttle control and rotation speed control. Rotation speed control is superior to throttle control in energy saving performance. Rotation speed control can be classified into mechanical control, like fluid joint and secondary resistance control, and into electric control, like Scherbius control and inverter control.

Descriptions

Depending on the motor types, there are several methods of controlling the fan rotation speed by varying the rotation speed of the motor that drives the fan. The representative static Scherbius control is explained here.
A wound-rotor induction motor for a large fan, like a preheater ventilation fan, used to be controlled by secondary resistance control that changes a rotation speed with a variable resistor on the secondary side. The typical variable resistor is liquid resistor. This control method is more economical than any other method because the structure is simple. However, the method also has disadvantages that the rotation speed changes by steps and that the efficiency is low, compared with other methods, because the secondary resistance loss becomes greater at a low speed.
Low efficiency attributable to the secondary resistance loss did not matter in the past production for maximum output but began to appear a problem during the long-term suppressed production. Replacing this, the static Scherbius control was aggressively adopted as a control method of high efficiency.
The static Scherbius control changes the rotation speed by applying a voltage to the secondary circuit. Of the secondary power, the secondary slip power is converted into AC by an inverter for the primary power (power supply).
Therefore, this control method features higher efficiency than secondary resistance control and a smaller loss attributable to a decrease of power factor at a low speed. However, the cost is higher.



Secondary resistance control　　Static Scherbius control

Results

Control Method	Output (kW)	General Efficiency (%)	Input (kW)	Power Saving (kW)
Scherbius control	1,487	93.0	1,599	220
Secondary resistance control	1,487	81.7	1,819	--

Cost estimation

270 thousand US$ (Motor ratings: 2,350 kW, 6 P, 3,300 V, and 60 Hz)　[1US$=¥110]

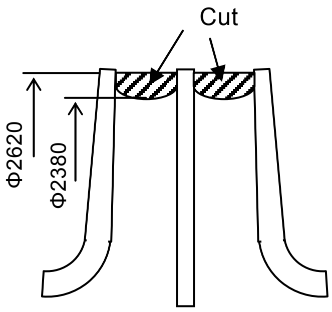
Related matters

Reference

Item	Fan impeller cutting	Application: Common
Background	At the cement manufacturing process, many fans are used to process combustion gas and air. These fans have necessary capacities for their positions. However, some fans may have excess margins which may increase as process changes. Since these margins waste power, fan impeller cutting is executed.	

Descriptions

Fan impeller (runner) cutting is generally executed as shown below.



When the rotation speed is the same, the wind rate is proportional to the ratio of impeller diameter. The pressure is proportional to the second power of the ratio and the electric power is proportional to the third power of the ratio. Therefore, the energy saving effect is great.
The limit of impeller cutting is generally said to be about 20% of the original diameter. Excess cutting may
1) lower the fan efficiency to an non-ignorable level,
2) reduce the mechanical strength of fan greatly,
3) increase mechanical instability at a high speed, causing vibration, or
4) cause problems easily due to insufficient margin.
When reducing the wind rate more 20% or more, the impeller should be replaced.

Results

Effect on 1700 kW kiln IDF (same wind rate)

	Impeller Diameter (mm)	Rotation Speed (min^{-1})	Power Consumption (kW)	Power Saving (kW)
Before cutting	2,620	1,200	1,475	--
After cutting	2,380	1,300	1,313	162

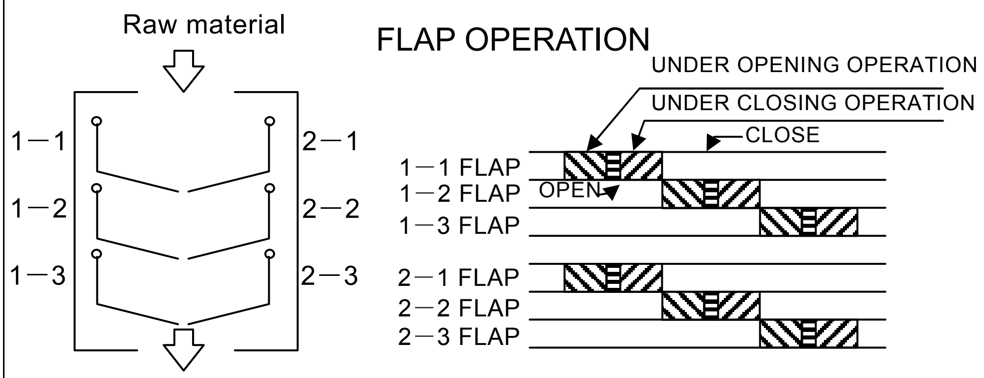
Cost estimation

Fan impeller replacement: 0.5 million US$ [1US$=¥110]
(Impeller cutting, including the main and side plates)
Vane cutting only: 27 thousand US$ [1US$=¥110]

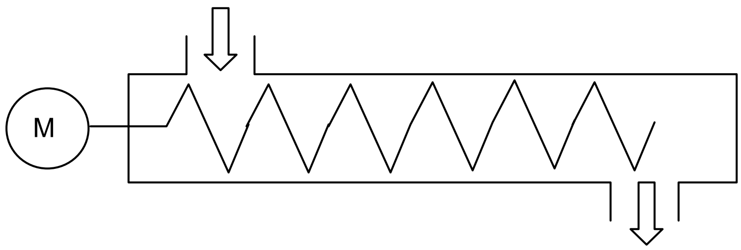
Related matters

Reference

<table>
<tr><th>Item</th><th>Material sealing</th><th>Application
Common</th></tr>
<tr><td>Background</td><td colspan="2">Undesired air leakage, which is made by huge pressure difference, especially occurred at material feed area of vertical mill, makes many operational troubles such as un desired increasing of gas flow, reduction of mill grinding capacity by poor drying performance caused by decreasing of gas temperature with cold leak air and undesired increasing of power consumption of mill fan caused by increasing of gas flow by leak air.
Air leakage can be reduced by using flap dampers of multiple stage or screw feeders having multiple screw shafts.</td></tr>
<tr><td>Descriptions</td><td colspan="2">The figures below show the 3-stage FD method.
The 3-stage FD consists of three flaps. Flaps sequentially open from top, middle and lower stage. When one stage is open, the remaining other stages are fully closed and their spaces are fully filled by materials. This makes strong seal for leakages.



In the double screw method, Raw materials are fed and discharged to vertical mill by the filled up conditions made by double parallel shaft screw rotating inward. This mechanism makes effective seal conditions.



</td></tr>
<tr><td>Results</td><td colspan="2">The 3-stage FD method reduced 30,000 m^3N/h or 30% of 100,000 m^3N/h leakage from 330,000 m^3N/h gas flow at the outlet of a vertical raw material mill. This corresponds to a reduction of 150 kW or 4% in IDF power.</td></tr>
<tr><td>Cost estimation</td><td colspan="2">3-stage FD system: 180 thousand US$ [1US$=¥110]</td></tr>
<tr><td>Related matters</td><td colspan="2"></td></tr>
<tr><td>Reference</td><td colspan="2"></td></tr>
</table>