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Development of New Type Ignition Apparatus for the Sintering Machine*



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(1) The multi-hole type nozzle and the slit type nozzle give uniform and short flames, and have realized more effective ignition.

(2) The burners are made adjustable to optimize ignition according to sintering condition.

Through the use of these new burners, the ignition energy consumption can be reduced by half to as low as 6 000 to 8 000 kcal/t-sinter without encountering any operational problems.

1 Introduction

Ignition furnaces have, to date, been used to ignite the coke breeze in the sinter mix (**Fig. 1**). In the ignition furnace method, the ignition of coke breeze requires a high ignition energy because of the nonuniform ignition intensity on the sinter mix surface. Furthermore, it is difficult to reduce energy consumption because the conventional ignition system cannot respond quickly to variations in sintering conditions (for example, bed height, pallet speed, etc.).

At the Chiba Works and Mizushima Works of Kawasaki Steel, the development of new ignition apparatus has been promoted through a review of the concept of ignition. As a result, the Chiba Works developed a multi-hole type ignition apparatus called the "line burner," which is capable of changing the burner height and angle; it was put into service at the No. 3 and No. 4 sintering machines in August 1983 (**Fig. 2**).

The Mizushima Works also developed an ignition apparatus called the "slit burner," having adjustable burner height. The slit burner was installed at the No. 4 sintering machine in March 1983 and at the No. 3 sintering machine in December 1984 (**Fig. 3**).

These new igntion apparatus ensure short, uniform flames of 0.6 m or less and are characterized by their unprecedentedly small size. Through the application of this equipment to actual production facilities, energy consumption has been reduced to half the conventional level of 14 000 to 16 000 kcal/t-sinter, i.e., to 6 000 to 8 000 kcal/t-sinter at both the Chiba and Mizushima Works.

This report describes the concept of the two new ignition apparatus, the line burner and slit burner, and results of their application to actual sintering machines.

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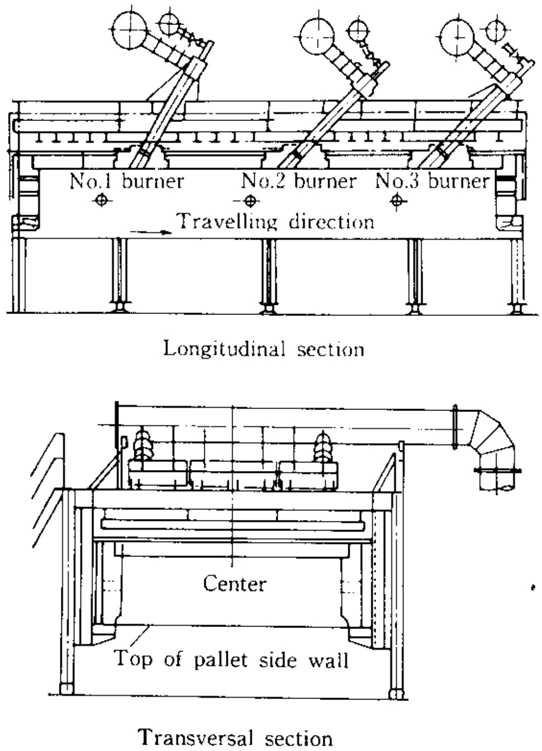

Fig. 1 Sectional views of conventional ignition furnace

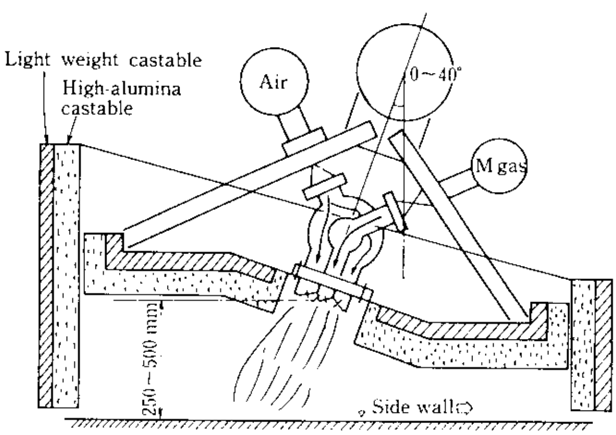

Fig. 2 Sectional view of line burner

2 Background of Development of New Ignition Apparatus

There have conventionally been two concepts of ignition of the sinter mix by the ignition furnace, i.e., flame ignition and atmospheric ignition. The former involves the direct firing by the combustion gas. The latter is the ignition provided in passing through a combustion atmosphere in the ignition chamber which are regarded as a kind of combustion chamber. Both method[1] have previously been studied, however, neither method has

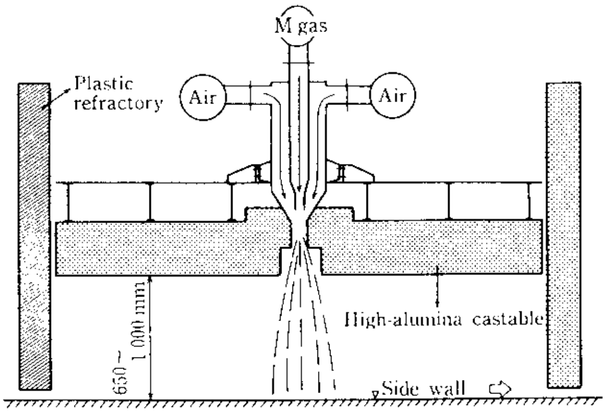

Fig. 3 Sectional view of slit burner

been possible to substantially reduce energy consumption because a decrease in ignition energy consumption results in a decrease in sinter yield.

On the other hand, ignition energy costs have increased due to the steep rise in fuel costs. Furthermore, it has become possible to prevent the decline of the yield even at reduced ignition energy consumption because of the development of techniques for segregation of size and component in the vertical direction of the sinter bed[2], techniques for controlling the negative pressure in the wind box below the ignition furnace[3], and the like. Therefore, the trend has been toward reduction of ignition energy consumption (**Fig. 4**).

In the conventional ignition furnace, it has been difficult to reduce the ignition energy consumption for the following reasons:

(1) The height of the ignition furnace is large due to formation of long flames (more than 1 m) with the conventional burner; the amount of radiation heat

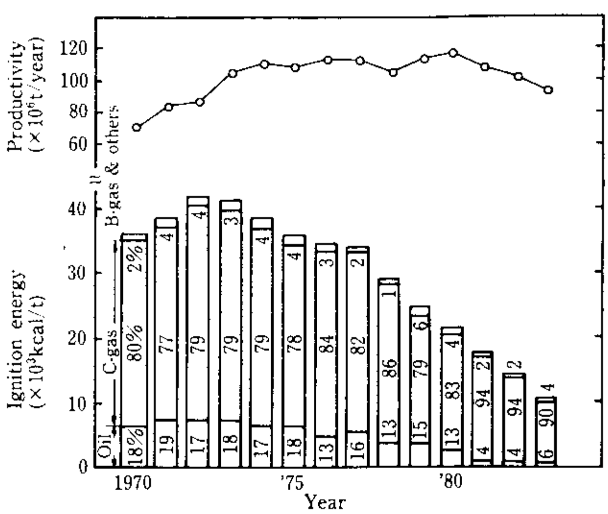

Fig. 4 Transition of sinter product and ignition energy consumption in Japan

considerably large from the furnace body.

(2) The long pitch of the burners makes widthwise ignition intensity uneven, resulting in excessive ignition.

(3) The ignition furnace is not capable of responding quickly to changes in sinter bed height and moisture content of the raw mix.

To solve these problems, Kawasaki Steel started on the development of new ignition apparatus.

3 Basic Concept of New Ignition Apparatus

3.1 Mechanism of Ignition

Conditions for the ignition of the raw mix had not previously been clarified. Before the development of the new ignition apparatus, therefore, a laboratory investigation was made into ignition conditions.

In the experiment, the sintering bed was charged with sinter mix. While suction from below the sintering bed continued, ignition was judged according to the condition of the sinter under varying suction temperatures and suction times. An electric furnace served as the ignition furnace.

Results of the experiment are shown in **Fig. 5**. Ignition conditions can be modified by changing the surface temperature of the sinter bed and holding time. When the surface temperature of the sinter bed is low, it is necessary to lengthen holding time. However, a short holding time suffices if the sinter bed surface temperature can be increased. In this case, the product obtained by multiplying holding time by pallet speed represents the ignition length of the bed surface and is a factor that determines the dimensions of the ignition apparatus. Therefore, the ignition apparatus can be of small dimensions if a burner, ensuring a short, uniform flame, is developed and the surface temperature of the sinter bed

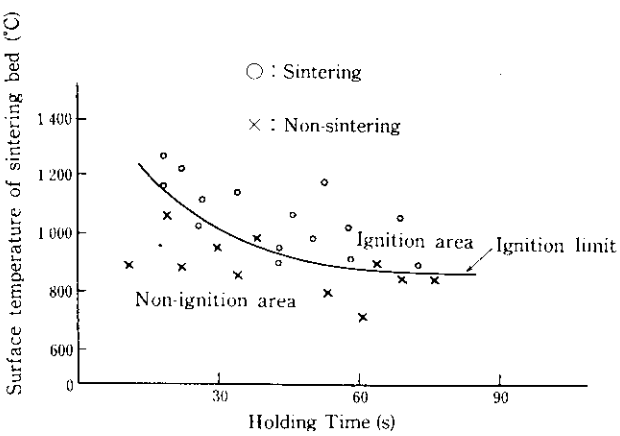

Fig. 5 Relation between holding time and surface temperature of sintering bed

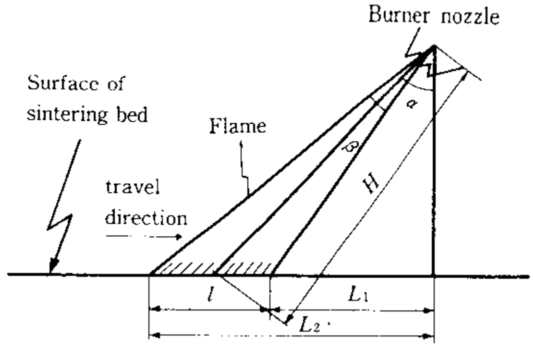

Fig. 6 Schematic diagram for burner inclination angle changes

can be increased.

Incidentally, when the pallet speed of the strand and the moisture content of the raw mix are changed in actual operation, it so happens sometimes that heat is consumed in the temperature rise of the raw mix and the evaporation of moisture content, with the result that holding time cannot be maintained and the critical ignition conditions can not be met. One solution to this problem is to retain holding time by changing the burner angle.

The concept of changing the line burner angle can be described as follows: When the burner angle (from the perpendicular direction) is too small, it is geometrically impossible to retain holding time. When this angle is too large, however, the ignition intensity decreases and ignition does not occur. Therefore, there are an upper and a lower limit to the burner angle. As shown in **Fig. 6**, if the burner angle is denoted by $\alpha(°)$, the flame spread angle by $\beta(°)$, the red hot length of bed surface by l(m), and the flame length from the burner nozzle to the bed surface by H(m), then the following equation holds:

$$l = PS \times t = L_2 - L_1 = H \cos\alpha\left[\tan\left(\alpha + \frac{\beta}{2}\right) - \tan\left(\alpha - \frac{\beta}{2}\right)\right] \quad \cdots\cdots (1)$$

where PS: Pallet speed (m/min)

t: Holding time (min)

Minimum burner angle relative to pallet speed is calculated by Eq. (1).

When the burner angle is large, ignition energy consumption per unit area (ignition intensity) decreases; and ignition does not occur. For this reason, there is an upper limit to burner angle if ignition intensity is to be retained within a certain range:

$$l = Q(I.I. \times W) \quad \cdots\cdots (2)$$

where Q: Energy consumption (kcal/h)

$I.I.$: Ignition intensity (kcal/m$^2 \cdot$ h)

W: Pallet width (m)

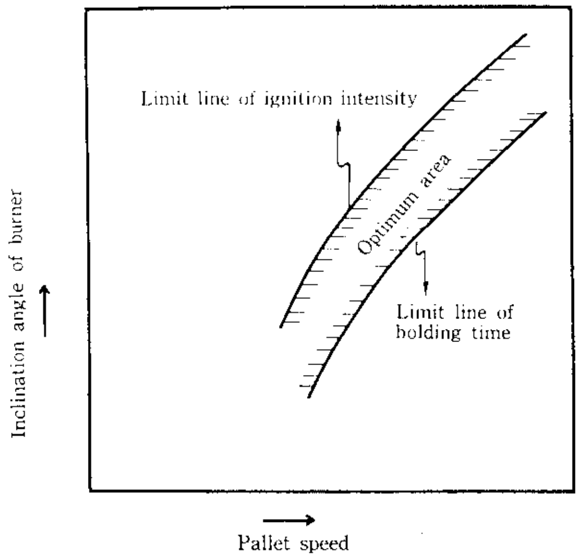

Fig. 7 Relation between pallet speed and burner inclination angle for optimum range

It is apparent from Eqs. (1) and (2) that optimum burner angle will fall within the range shown in **Fig. 7**.

3.2 Selection of Burners

The ignition burner for sintering must meet the following basic conditions:

(1) Uniformity of flames in the width direction of the burner
(2) Formation of short flame
(3) High flame temperature

At the Chiba Works, condition (1) above was met by the multihole type, conditions (2) and (3) by the nozzle mix type. At the Mizushima Works, condition (1) was achieved with the slit type, conditions (2) and (3) with the premix type. Results of an investigation into the formation of short flames are shown in **Fig. 8**. The air and fuel gas mixed well and the shortest flame was obtained when the intersecting angle of air and gas was 90° in the line burner and when the slit index—quotient obtained by dividing the slit length by the slit width of burner nozzle tip—was more than 7 in the slit burner.

Next, an investigation was made into conditions of air and gas velocities under which sinter mix is ignited by the line burner.

(1) When the air and fuel gas velocities decrease, ignition intensity decreases due to flame buoyancy.
(2) When the air and fuel gas velocities increase, the raw mix on the bed surface is scattered, resulting in uneven sintering.
(3) When the air velocity increases, the flame spread angle becomes acute and the holding time cannot be maintained.
(4) When the fuel gas velocity is high relative to the air velocity, the air and fuel gas do not mix well and the flame becomes long.

To determine optimum limits to air and fuel gas velocities, several types of burner nozzles with differing diameters were fabricated for both the air and the fuel gas. An investigation was then made into the effect of the air and fuel gas velocities at a constant volume of combustion. **Figure 9** shows results of this investigation. A point at the center of the optimum range for air and fuel gas velocities shown in Fig. 9 was adopted in the design of the new ignition apparatus.

4 Design of New Ignition Apparatus

4.1 Burners

The following design considerations were adopted in order to obtain uniform short flames.

(1) Line burner
  (a) Adoption of a multihole type in which multiple air and gas ports are arranged in two rows in the width direction of pallet
  (b) Adoption of a nozzle mix method in which the

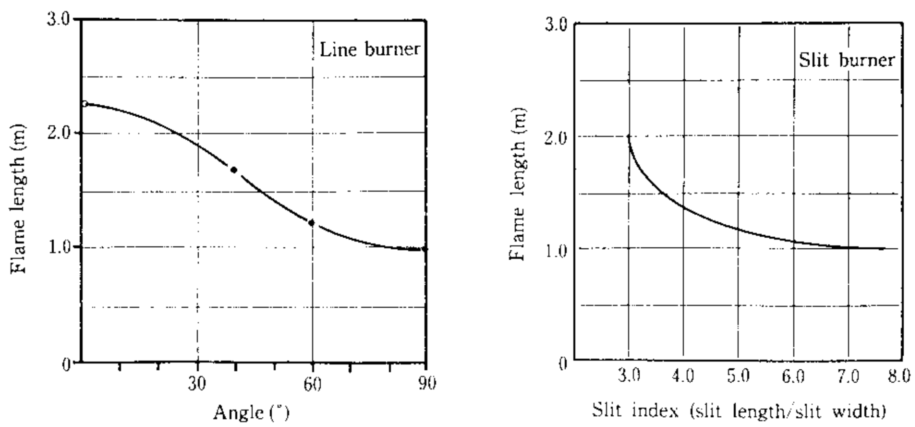

Fig. 8 Effect of air/gas intersect angle and slit index on flame length

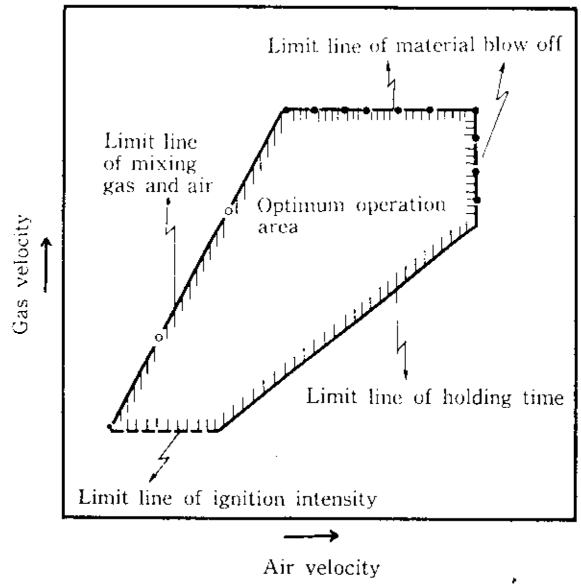

Fig. 9 Optimum operation area of air- and gas-velocity by line burner

fuel gas stream and air stream intersect at 90°

(2) Slit burner
   (a) Adoption of an air-gas-air sandwich construction in which the tips of all passages are connected in the width direction of pallet
   (b) Adoption of a premix method by which the fuel gas and air are premixed

4.2 Burner Chambers

The following measures were adopted to ensure the long life of the ignition apparatus:

(1) Line burner
   (a) Protrusion of only the burner nozzle into the hood
   (b) Adoption of heat-resistant cast steel burner nozzles

(2) Slit burner
   (a) Coating of the burner tip with a refractory castable

4.3 Apparatus Holding Mechanism

Burner were designed for quick response to variations in sintering operation conditions, e.g., sinter bed height and pallet speed.

(1) In the line burner, to adapt to changes in height, each of the gas pipe and air pipe connections is a flexible hose; adjustments can be made by screw jacks installed on both sides of the ignition apparatus support. In the silt burner, a motor-driven cylinder is installed on the ignition apparatus and adjustments are made by starting a cyclo-motor.

(2) In the line burner, a hinge mechanism was adopted so that the burner angle α can be adjusted in the range of 0° to 40°.

(3) In connection with the height changing function, the hood is separated into a top hood and a side hood. Only the top hood moves in conjunction with the burner proper.

A comparison of the equipment specifications of the conventional ignition furnace and the line burner in the Chiba No. 3 sintering machine is shown in **Table 1**.

Table 1 Comparison of conventional ignition furnace and line burner (Chiba No. 3 sintering plant)

Item \ Specifications	Conventional ignition furnace	Line burner
Type of furnace	Bottom open box, top burner type	Line burner
Dimension (mm)	3 600 W × 7 500 L × 1 000 H	3 600 W × 2 200 L × 250 H
Furnace volume	27 m^3	2 m^3
Max. combustion cap.	18.3 × 10^6 kcal/h	3.5 × 10^6 kcal/h
Burner type	Nozzle mix type	Nozzle mix type
Fuel	Mixed gas (2 300 kcal/Nm^3)	Mixed gas (2 300 kcal/Nm^3)
Number of burners	14 burners/line × 3 lines	Multi-hole type × 1 line
Gas pressure	250 mm aq (at burner)	250 mm aq (at burner)
Air pressure	250 mm aq (at burner)	250 mm aq (at burner)

5 Application to Actual Sintering Machines

The above-mentioned new ignition apparatus have been installed in actual sintering machines. Line burners were installed in the Chiba No. 3 and No. 4 sintering machines in August 1983, and slit burners in the Mizushima No. 3 sintering machine in December 1984 and in the Mizushima No. 4 sintering machine in March 1983. In order to reduce ignition energy consumption in the use of these new ignition apparatus, ignition limits and effects of operation parameters on ignitability were clarified through study of results in measurement of the temperature distribution at the bed surface. Optimum operation parameters were thus determined.

5.1 Selection of Optimum Ignition Conditions

The method of measuring the surface temperature of the sinter bed during ignition and an example of an actual measurement are shown in **Fig. 10**. Thermocouples were placed on the sinter mix on the pallet, and

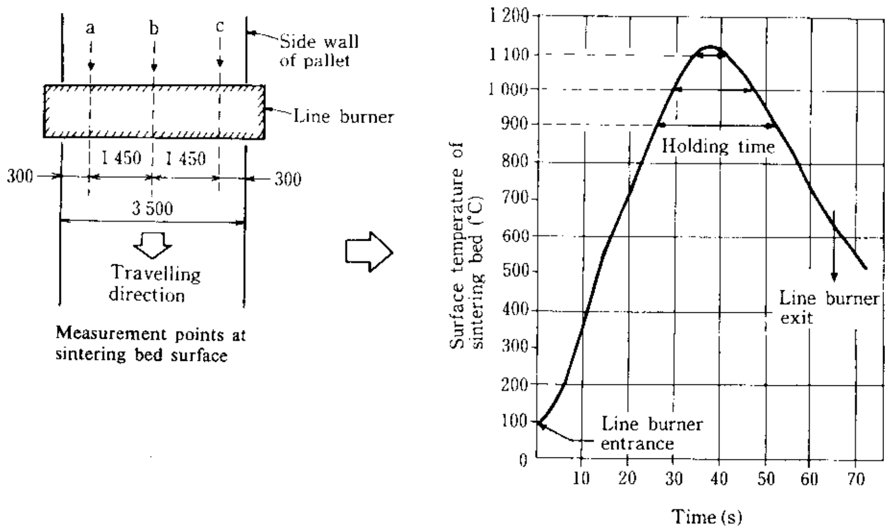

Fig. 10 Surface temperature measurement and an example of its results

the temperature from the entry to the exit side of the burner hood was measured while the pallet was moving. Three measurement points in the pallet width-wise direction were used. The temperature distribution obtained, using the average of the temperatures measured at the three points, was plotted. From this, time-wise temperature distribution chart, the holding time at temperature levels above 900°C was determined. The relationship between ignition limits and operation parameters was clarified from these values.

(1) Ignition Limits and Conditions for Stable Ignition

An investigation was made into the relationship between the ignition energy consumption and the surface temperature of the sinter bed in a line burner with a burner height of 300 mm and a burner angle of 25°. Results of the investigation are shown in **Fig. 11**.

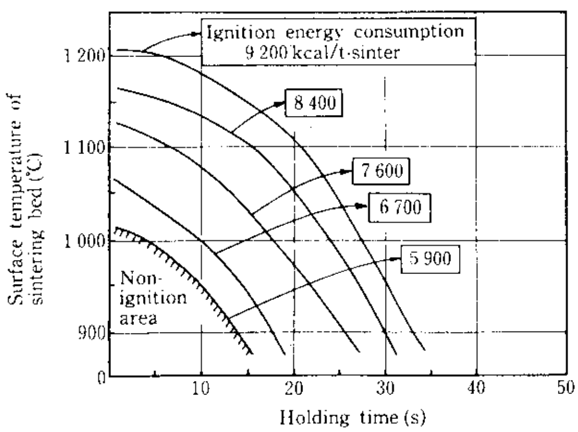

Fig. 11 Relation between holding time and surface temperature of sintering bed

When ignition energy consumption is reduced, a non-ignition area is formed if a temperature distribution, corresponding to an ignition energy consumption of 5 900 kcal/t-sinter, is reached as shown in the figure. It was ascertained, therefore, that the maintenance of stable operations requires a retention of temperature distribution corresponding at least to an ignition energy consumption of 6 700 kcal/t-sinter. Thus, it was possible to ensure stable operation at the Chiba Works and Mizushima Works after grasping ignition limits and conditions for stable ignition. At the same time, operation parameters were optimized, as described below, in order to reduce ignition energy consumption.

(2) Burner Height

It was found that a decrease in the burner height results in an increase in the surface temperature and that the ignition energy consumption thereby can be reduced (**Fig. 12**). In this case, aiming at the reduction of ignition energy consumption, it is important that the maximum temperature point of the flame reach the sinter bed surface.

(3) Burner Angle

As described in Sec. 3, the line burner angle was so set up as to fall within the range defined by ignition intensity and the high-temperature holding time for a given pallet speed.

(4) Moisture Content of Raw Mix

When the moisture content of the raw mix was changed, ignitability improved with decreasing moisture content. Therefore, it is necessary to operate at the minimum moisture content necessary for quasi-particle formation in the raw mix (**Fig. 13**).

(5) Yield

An experiment was conducted using the line burner

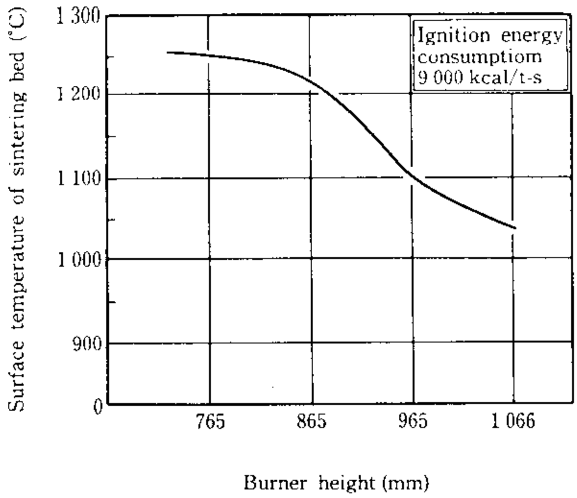

Fig. 12 Effect of burner height on ignition conditions with slit burner

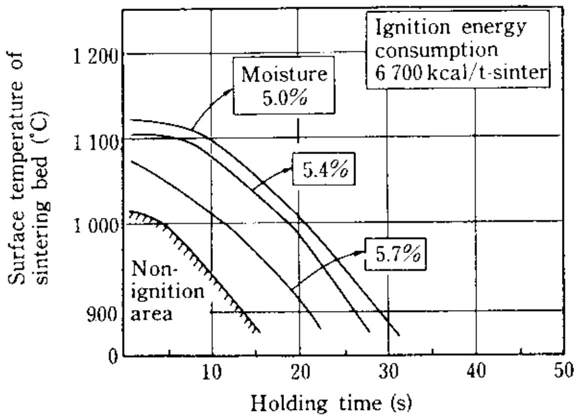

Fig. 13 Effect of moisture content in sinter mix on the ignition conditions with line burner

to investigate the relationship between ignition energy consumption and return fine ratio when productivity is changed. In this experiment, burner height was constant at 300 mm, and burner angle, at 25°. The results shown in **Fig. 14** indicate that, to maintain a permissible return fine ratio for the operation, ignition energy consumption can be reduced to about 6 000 kcal/t-sinter at a productivity of 1.3 $t/m^2 \cdot h$ or less and to about 7 000 kcal/t-sinter at a productivity of 1.5 $t/m^2 \cdot h$.

When the unit ignition energy consumption is further reduced, the return fine ratio increases abruptly. Above this critical point, the return fine ratio scarcely changes even if the unit ignition energy consumption is again increased.

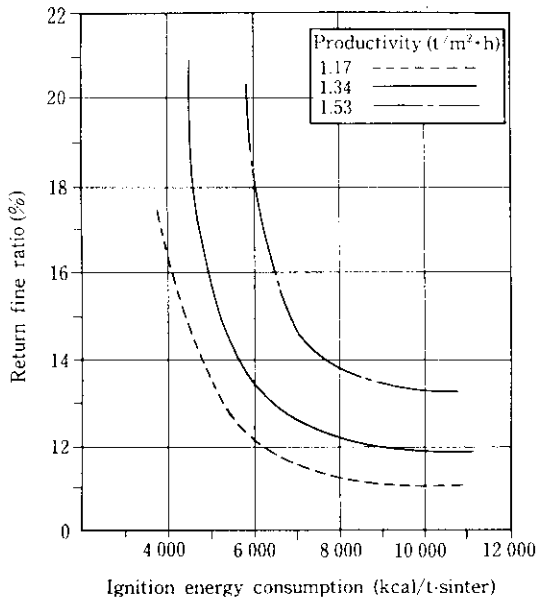

Fig. 14 Relation between ignition energy consumption and return fine ratio with line burner

5.2 Results of Operation

The following operation results were obtained in the sintering plants at the Chiba and Mizushima Works following investigation of the relationship between operation parameters and ignitability for the line burner and

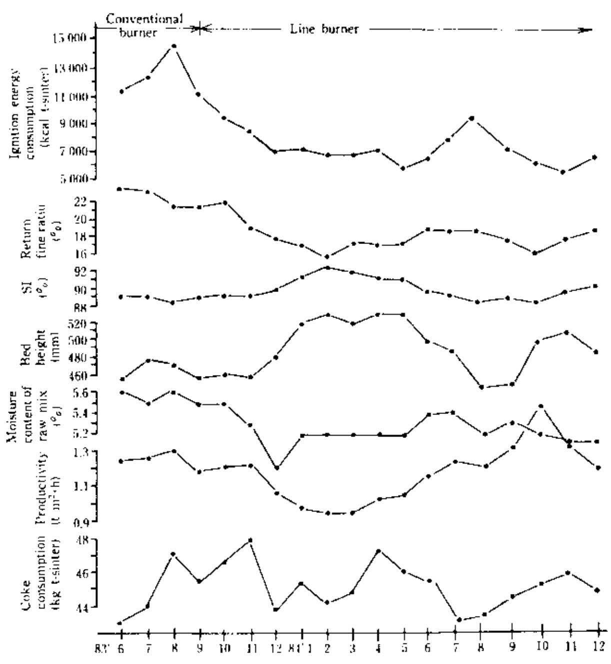

Fig. 15 Comparison of operational results between before and after the use of line burner at Chiba No. 3 DL

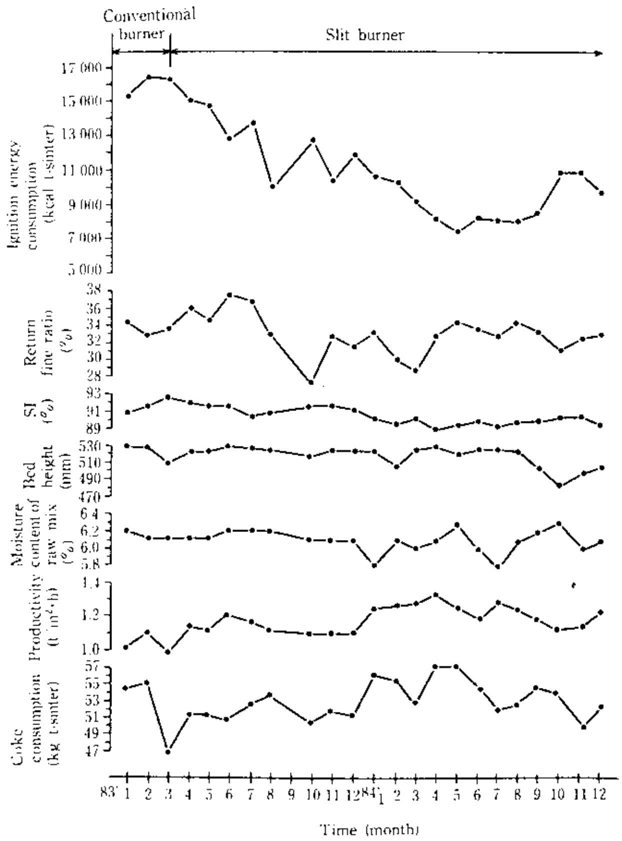

Fig. 16 Operational results between before and after the use of slit burner at Mizushima No. 4 DL

the slit burner and optimization each parameter.

Operation results for the Chiba No. 3 sintering machine are shown in **Fig. 15**, and those for the Mizushima No. 4 sintering machine in **Fig. 16**. At both Works, through the implementation of the new ignition apparatus, ignition energy consumption was reduced to half the conventional 14 000–16 000 kcal/t-sinter level, i.e., to 6 000–8 000 kcal/t-sinter without adverse effects on the quality of sinter products.

A general view of the line burner is shown in **Photo 1**, and that of the slit burner in **Photo 2**.

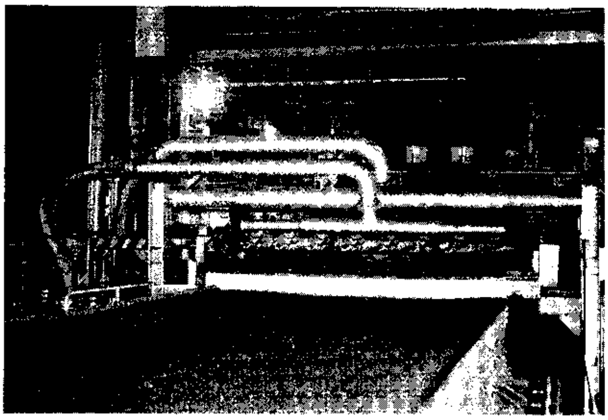

Photo 1 General view of line burner

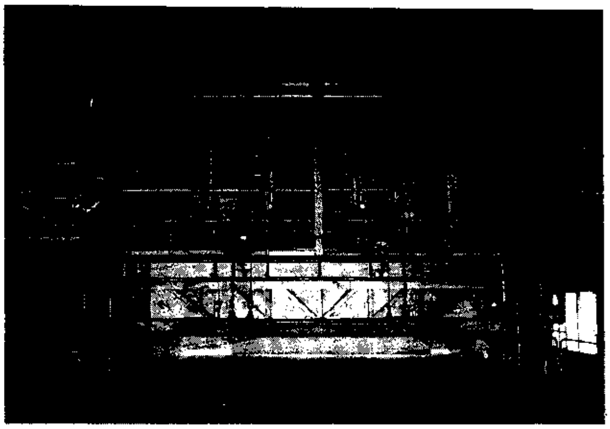

Photo 2 General view of slit burner

6 Conclusions

At the Chiba and Mizushima Works, new ignition apparatus for sintering, the line burner and the slit burner, were developed following a thorough review of the concept of ignition.

The line burner was applied to the Chiba No. 3 and No. 4 sintering machines in August 1983. The slit burner was installed at the Mizushima No. 4 sintering machine in march 1983 and at the Mizushima No. 3 sintering machine in December 1984.

These new ignition apparatus, with their variable burner height and angle functions, have advantages over the conventional ignition furnace in terms of quick response to changes in operating conditions. The new ignition apparatus were put into practical use and techniques for their optimum operation were established. As a consequence, ignition energy consumption has been substantially reduced without adversely affecting the quality of sinter products.

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