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Countermeasures for Prevention of Air Leakage at Sintering Machine and Their Effects

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In addition, a useful means of finding out the air leakage volume was investigated to evaluate the effects of countermeasures for prevention of air leakage.

1 Introduction

Recently, a notable trend of sintering plants is the promotion of energy saving measures. This is seen in the construction of exhaust heat recovery plants and the use of cost-minimum operations, and it all reflects the current energy conditions of steelworks. At this stage, the reduction of air leakage volume remains as an important task in the area of energy saving. Reduction of air leakage offers benefits not only in terms of energy saving, such as reductions of blower electrical requirements and combustion gas in the denitrification furnace, but also in terms of various operational factors such as improved productivity.

At Chiba Works' No. 4 Sintering Plant, countermeasures for prevention of air leakage at the sintering machine were executed for both equipment and operation, with significant results. This report describes these countermeasures and their effects.

2 Equipment Configuration and Operating Costs of Chiba No. 4 Sintering Plant

The facility configuration of the No. 4 Sintering Plant is shown in **Fig. 1**. Desulphurizing and denitrification equipment is installed for exhaust gas processing, and the exhaust heat recovering facility is included in the cooling line for the sintered product. In order to minimize overall operating costs, therefore, the sintering operation must take into consideration coke breeze consumption, power used in blowers (for exhaust main, desulphurization, and denitrification), volume of combustion gas fed to denitrification furnace, and steam recovered by coolers. As shown in **Fig. 2**, when air leakage is reduced, operating costs are lowered remarkably.

On the other hand, the following restrictions must be considered for the protection of sintering plant facilities:
(1) The temperature of the exhaust gas at the entry

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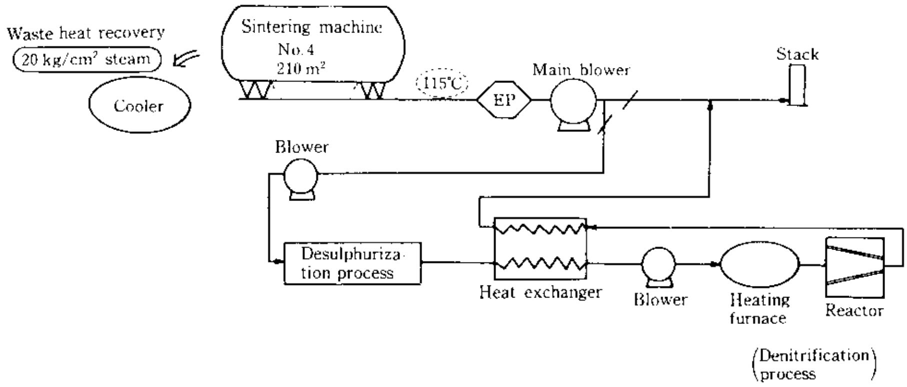


Fig. 1 Chiba No. 4 Sintering Plant

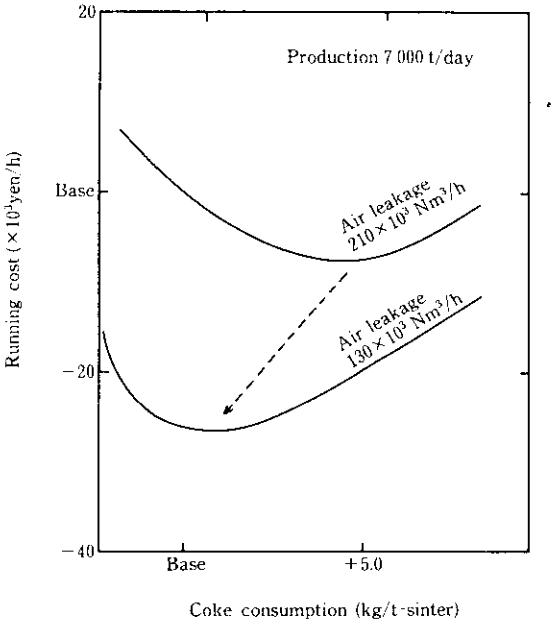


Fig. 2 Changes in operating costs with decrease in air leakage

side of the electrostatic precipitator (EP) must be higher than 115°C to prevent acid corrosion of the exhaust gas facilities.

(2) The negative pressure at the entrance of the main blower must be lower than 1 950 mm H_2O because of the duct strength and blower characteristics.

To cope with air exhaust volume variations, the pressure at the main blower exit is controlled by adjusting the rotation speed of the desulphurization blower, which is positioned in series with the main blower. Therefore, the reduction of air exhaust volume directly results in reduction in blower electricity consumption.

3 Estimation of Volume of Air Leakage in Sintering Operation

3.1 Exhaust Gas Volume

As shown in **Fig. 3**, total exhaust gas volume is the sum of the volume of three different types of exhaust gases.

(1) Combustion gas volume, required for combustion of coke breezes and heat transfer in strand (i.e. necessary gas volume for sintering process)
(2) Suction gas volume at discharge end, required for cooling sintered products on strand
(3) Mechanical air leakage volume, drawn in through mechanical gaps

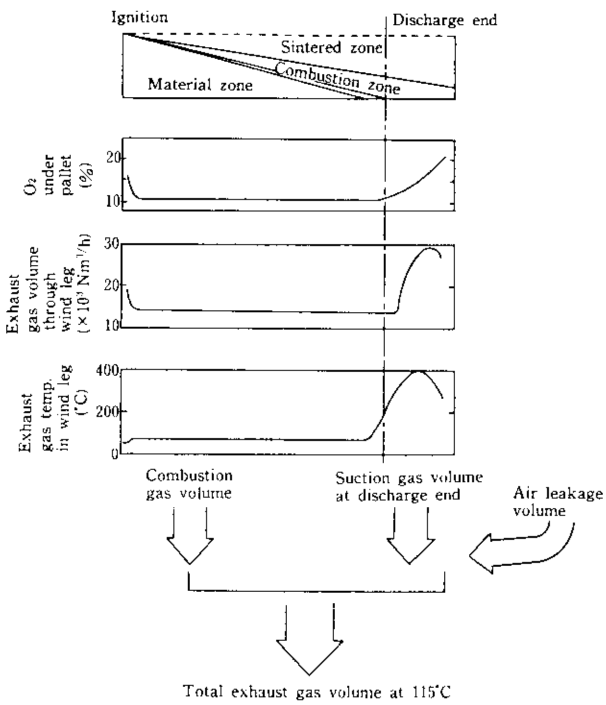


Fig. 3 Exhaust gas distribution

Table 1 Classification and characteristics of exhaust gas

Symbol	Classification of exhaust gas volume	Temperature (°C)	O_2 content (%)	Factors
Q_A	Combustion gas volume	60～70	11～12	Production quantity (Amount of sinter mix)
Q_B	Suction gas volume at discharge end	300～500	15～21	Burn through point
Q_C	Mechanical air leakage volume	0～30	21	Gap or opening area

The characteristics of these exhaust gases are shown in **Table 1**.

To keep the temperature of the exhaust gas above 115°C, the suction gas volume at the discharge end is determined by considering the balance between the combustion gas and mechanical air leakage vôlumes and controlled by adjusting the position of BTP (burn through point). Therefore, reduction of mechanical air leakage results in a decrease in the suction gas volume at the discharge end. Increases in the coke blending ratio also cause the suction gas volume to decrease due to the consequent rise in temperature of the exhaust gas at the discharge end.

In this report, in addition to mechanical air leakage volume, suction gas volume at the discharge end is regarded as a type of leakage volume in the sintering operation, and the sum of these volumes is defined as the total volume of air leakage.

3.2 Estimation of Volume of Air Leakage

Some theoretical studies of the combustion gas volume required for sintering process have been made.[1,2] Shibata et al.[2] showed the following relation:

$$V_0 = C_s / C_g \cdots\cdots\cdots\cdots (1)$$

where V_0: combustion gas volume per unit material weight

C_s: specific heat of solid (kcal/kg · deg)

C_g: specific heat of gas (kcal/kg · deg)

The Shibata study concluded that the gas volume required for moving the heat wave from the top to the bottom of the bed is fixed independent of operational conditions such as bed height and suction pressure. In other words, because the value C_s/C_g can be considered to be almost constant in practical conditions, combustion gas volume changes in proportion to the weight of the material fed onto the pallet.

The relation between feeding material on the pallet and exhaust gas volume is shown in **Fig. 4**. This data consists of monthly averaged values taken from the actual operation at the No. 4 Sintering Plant from January 1983 to June 1984. **Figure 5** is obtained from Fig. 4 by correcting for effects of seasonal changes in atmospheric

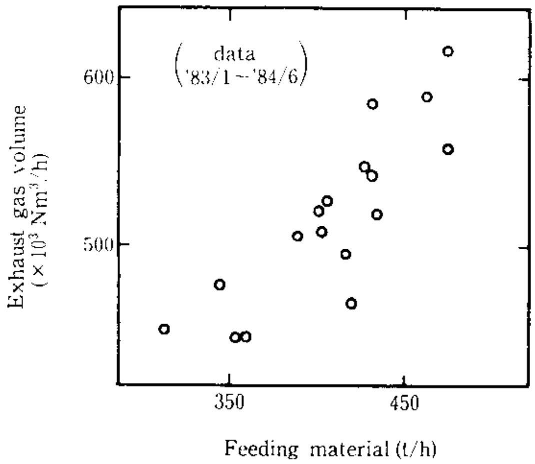


Fig. 4 Relation between feeding material on pallet and exhaust gas volume

and exhaust gas temperatures on exhaust gas volume. There is a positive correlation between exhaust gas volume and feeding material. The intercept and gradient of the regression line in Fig. 5 can be regarded as the air leakage volume and combustion gas volume, respectively (see **Fig. 6**); that is, changes along this line are the inevitable result of increases or decreases in production. The change in air leakage volume can be estimated from the displacement of this line in the direction of Y-axis.

4 Countermeasures for Air Leakage Prevention

This section describes the concepts and actual measures taken for air leakage prevention.

4.1 Mechanical Air Leakage in Moving Units

The following must be taken into consideration regarding the moving units:

(1) The 102 units of pallet (40 units in suction area) are operated continuously, and the air seals which are usually attached to pallets slide 60 m on the slide beds in the suction area.

(2) The side walls attached to the pallets tend to wear because they move in contact with neighboring side walls, are also susceptible to thermal deformation and cracking due to cyclic thermal stress. These latter problems are caused by the fact that pallets enter ignition units at 1 h interval and receive heating of about 1 000°C to their upper portions.

(3) The moving units go through an atmosphere which contains a large amount of fine particles of iron and sintered ores.

Based on these conditions, primary countermeasures for air leakage prevention must include:

(1) The relative positions between pallet wheels, air seals, and slide beds must be adjusted to remain

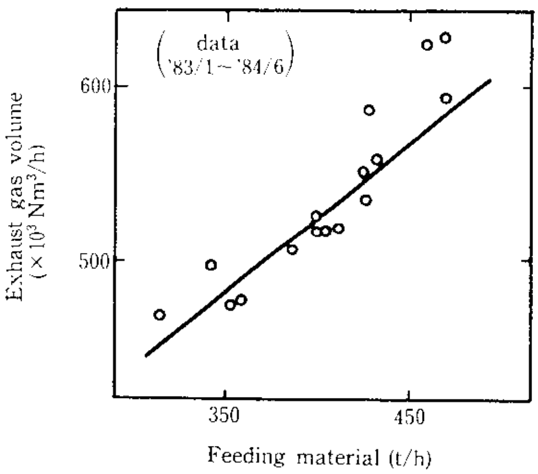


Fig. 5 Relation between feeding material on pallet and exhaust gas volume with correction for seasonal changes in exhaust gas temperature and air temperature

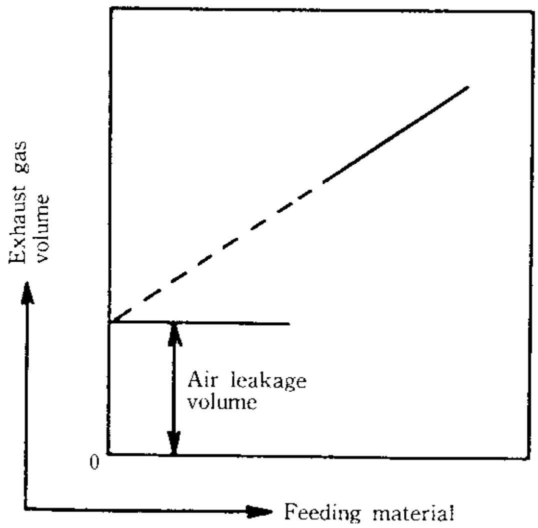


Fig. 6 Definition of air leakage volume

within the standard value range.

(2) Cracking must be inhibited and deformation minimized by reducing divided parts of side wall and by developing materials and structures highly resistant to thermal stress and deformation.

In addition to these countermeasures, a facility diagnostic technique for the displacement of the parts mentioned in (1) must be established and the structure of the moving unit must be improved to allow easy maintenance, including quick and economical repairs.

However, with only these countermeasures, it is not possible to suppress air leakage volume lower than a certain level. Therefore, secondarily, it is necessary to work out countermeasures for inevitably existing small mechanical gaps and to develop and install a new seal unit. The new unit must satisfy the following conditions so that it effectively prevents air leakage:

(1) The seal must provide stable contact, responding to minute displacement variations. That is, the material and structure of the seal must allow quick, flexible movement, and the seal must be attachable as is appropriate in consideration of the direction of the air leakage.

(2) The seal must be suitable for the atmosphere of the installation site. That is, seal movement cannot be affected by the invasion of a certain amount of dust, and the seal material must be stable at ambient temperatures.

4.2 Mechanical Air Leakage at Fixed Parts

Most of air leakage at fixed parts, e.g. exhaust gas ducts, is caused by corrosion holes. Existing leakage can only be corrected by repair work, so it is important to reduce the frequency of occurrence of corrosion holes. The main countermeasure for air leakage is control of exhaust gas temperature maintaining the temperature of the inner surface of the iron skin above dew point, and application of corrosion-resistant lining to localized parts where low temperature is a problem.

4.3 Air Volume Not Contributing to Sintering on Strand

The greater volume of air which passes over the strand without contributing to sintering is the suction gas volume at discharge end, mentioned above. The remainder is the air volume caused by nonuniformity of air passing in the vicinity of side wall, etc. The suction gas volume at the discharge end is necessary to maintain the temperature of the exhaust gas for corrosion hole prevention, as described in Sec. 4.2. Raising the temperature of the exhaust gas at the discharge end in order to reduce this volume is effective for preventing air leakage.

To prevent the nonuniformity of air passing, it is important to make air-passing-resistance uniform by compressing the raw mix near the side wall, by uniformly charging raw mix along the width and length of the pallet, and by uniform ignition.

4.4 Air Leakage Prevention Countermeasures Actually Executed

At the No. 4 Sintering Plant, the execution of countermeasures for air leakage prevention has been under way since September 1984. Typical examples include:

(1) Reduction of mechanical air leakage (see **Fig. 7**)
  - (a) Attachment of a new type of seal between air seal bar and air seal box
  - (b) Attachment of a new type of seal between air seal bar and slide bed
  - (c) Attachment of a new type of seal between air seal box and pallet

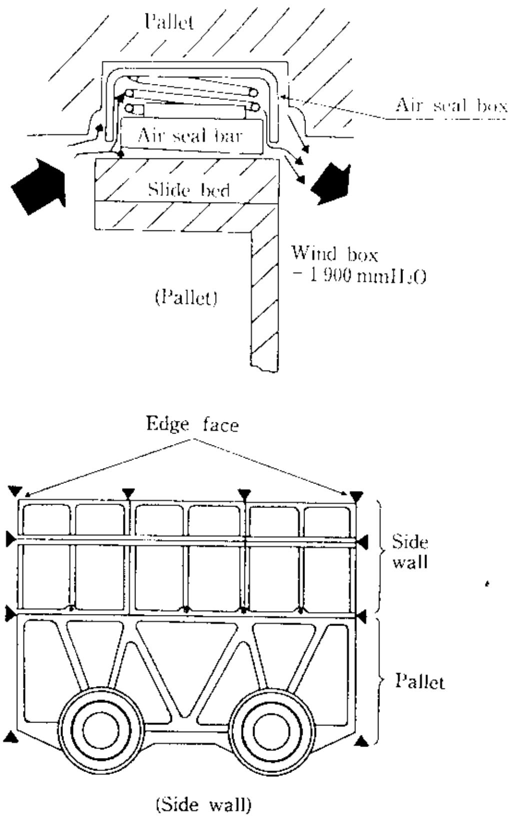


Fig. 7 Example of countermeasure for prevention of air leakage

(d) Use of single-unit side wall
(e) Attachment of seals to the end face of side wall and to the face in contact with pallet
(f) Corrosion prevention countermeasures for exhaust gas lines

(2) Reduction of leakage volume passing over strand
(a) Raising exhaust gas temperature at discharge end (switchover to high-FeO operation[3])
(b) Improvement of raw mix feeding mechanism (drum feeder, sub-gate control, etc.)
(c) Effective use of compression device for raw mix (side pressing roller, etc.)
(d) Uniform ignition by line burner[4]

The above countermeasures are shown in **Fig. 8** in terms of equipment, location, and cause of problem.

5 Results of Air Leakage Prevention Measures

5.1 Reduction of Air Leakage Volume

To confirm the effectiveness of air leakage prevention with the new types of seals for pallets and side walls, developed and applied at the No. 4 Sintering Plant, O_2 contents of exhaust gas were measured at the No. 8 wind leg (at the center of the sintering machine), with the results shown in **Fig. 9**. A Horiba type magnetic O_2 meter was used as the measuring sensor. From Fig. 9, it is clear that reduction in O_2 contents in areas where air

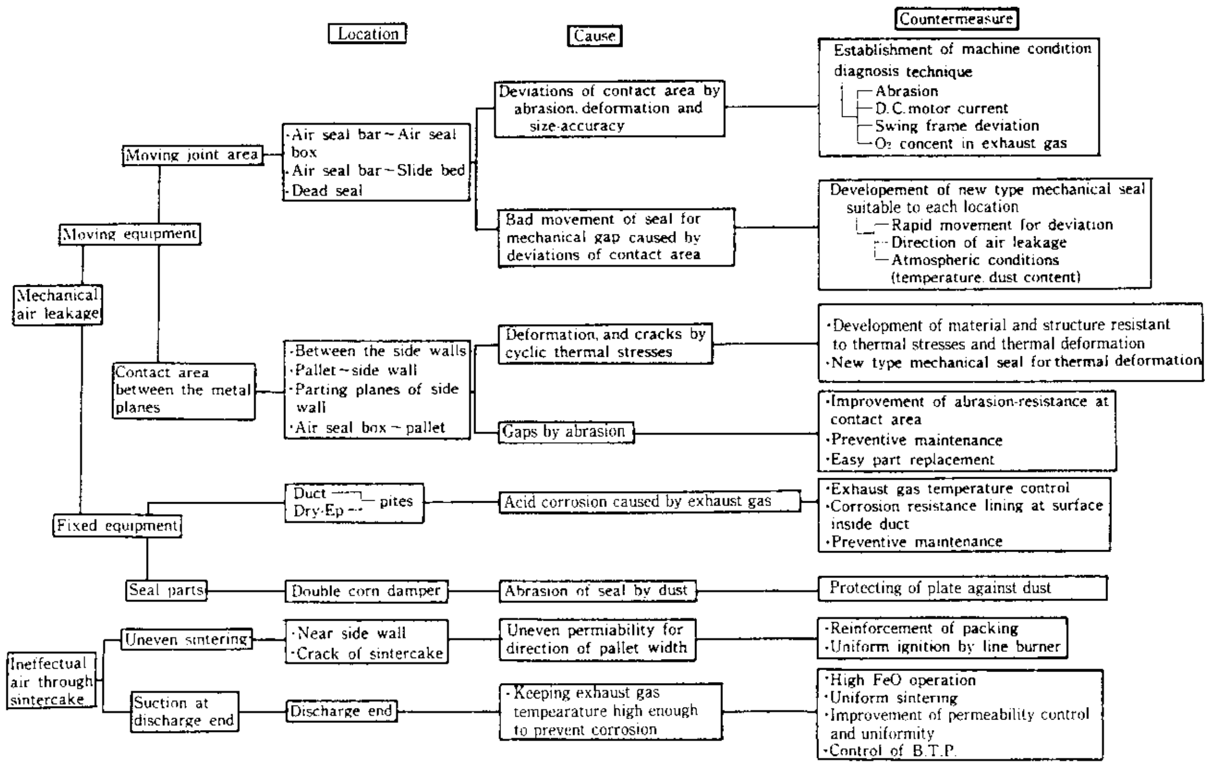


Fig. 8 Concept diagram for prevention of air leakage

leakage prevention countermeasures were applied is remarkable, indicating the effectiveness of the countermeasures.

Figure 10 shows the relationship between the amount of material on the pallet and exhaust gas volume, classified by periods in the air leakage prevention program. All values are daily averages. The change from period Ⓐ to Ⓑ corresponds to the switchover to high-FeO operation. The number of pallets and side walls with new type seals was increased from period Ⓒ to Ⓔ. At the No. 4 Sintering Plant, 102 pallets are used, therefore, in period Ⓔ, modification of almost all pallets had been completed.

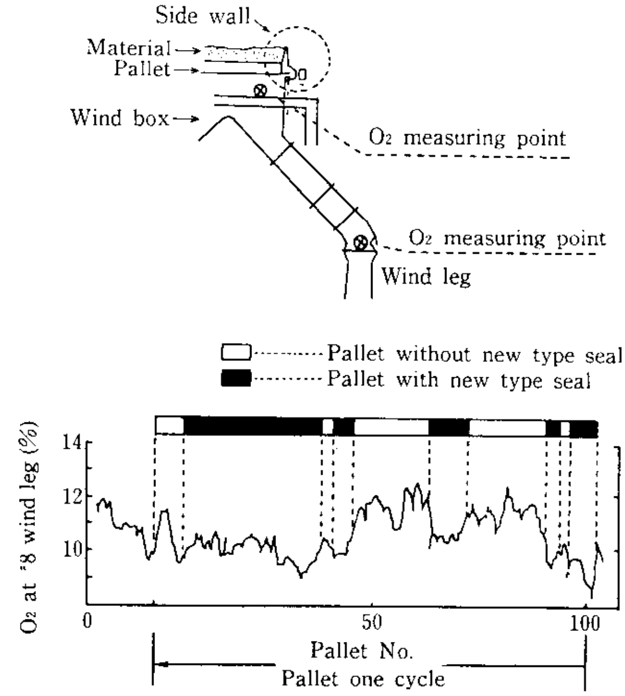
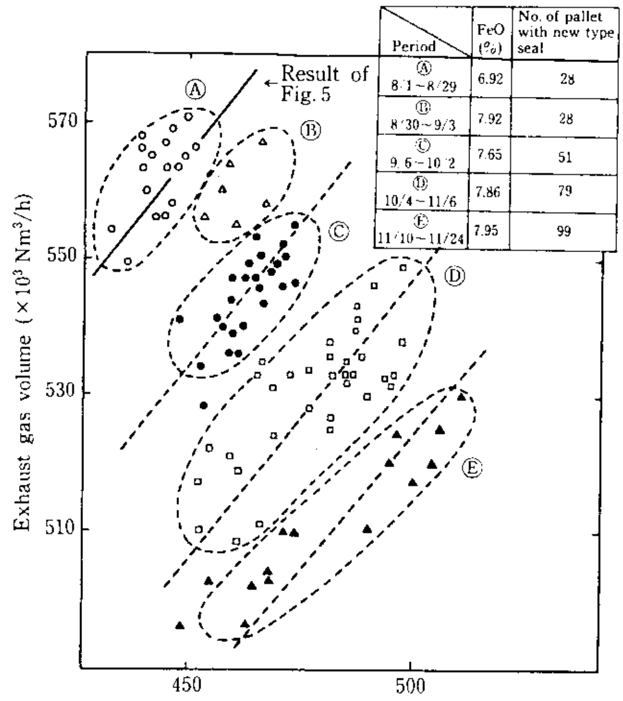


Fig. 9 Effect of new type air seal



Period	FeO (%)	No. of pallet with new type seal
Ⓐ 8/1~8/29	6.92	28
Ⓑ 8/30~9/3	7.92	28
Ⓒ 9/6~10/2	7.65	51
Ⓓ 10/4~11/6	7.86	79
Ⓔ 11/10~11/24	7.95	99

Fig. 10 Changes in relation between feeding material on pallet and exhaust gas volume with air leakage decreases

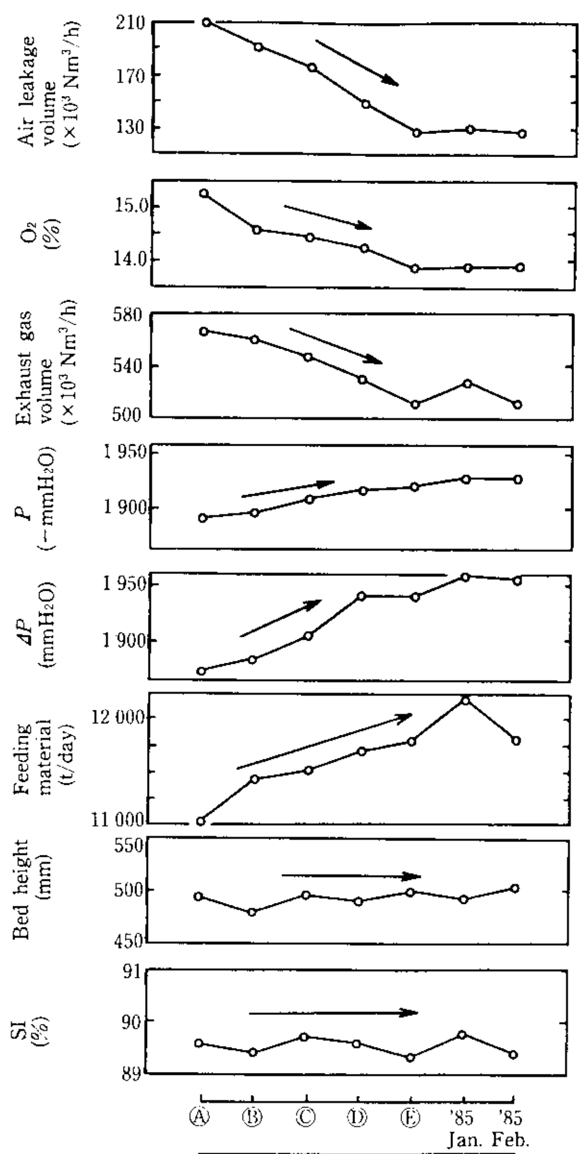


Fig. 11 Transition of sintering operation with air leakage volume

As is clear from Fig. 10, the relationship in the base period Ⓐ is the same as that in Fig. 5, and the regression lines are displaced in the direction of Y-axis with their gradients constant. The degree of displacement increased from Ⓑ to Ⓔ. This means, as explained in Sec. 3.2, that the leakage volume not contributing to sintering was reduced by 79 × 10^3 Nm^3/h (equal to 14% of total exhaust gas).

5.2 Effects of Reduction of Air Leakage volume

Figure 11 shows the transition of air leakage volume in the periods Ⓐ to Ⓔ in Fig. 10 and January and February 1985. The air leakage volume is maintained at lower levels following the period Ⓔ.

Figure 11 also shows changes in the O_2 content of exhaust gas, exhaust gas volume, negative pressure at the main blower entrance, and pressure difference between the suction and delivery sides of the main blower. Corresponding to the reduction of air leakage volume, O_2 content fell to a level in the 13% range, and both exhaust gas volume and pressure change according to the characteristic curve of the main blower. Changes in amount of raw material, bed height, and shutter index are also presented in Fig. 11. These indicate that it became possible to increase productivity without changing bed height as a result of the reduction of air leakage volume. The transitions of fuel consumption of the heating furnace and electric power consumption of the blowers (main + desulphurization + denitrification) are shown in **Fig. 12**. The reductions per unit weight (t) of material are 6 000 kcal and 2 kW · h, respectively.

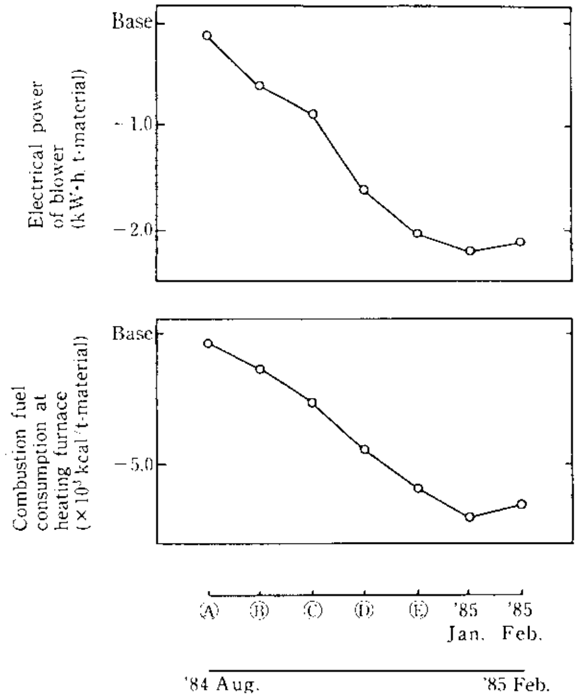


Fig. 12 Changes in electrical power (main blower + desulfurization + denitrification) and in fuel consumption

6 Conclusions

At the Chiba No. 4 Sintering Plant, air leakage volume has been markedly reduced by various countermeasures. Mainly, on the equipment side, pallets and side walls were improved, and secondarily, on the operation side, high-FeO operation was instituted and detailed modifications in the area of feeding material were carried out.

As a result, major reductions were achieved in electric power and furnace fuel costs. In addition, an increase in productivity has become possible without enlargement of the main blower capacity.

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