4

IMPROVEMENT OF THE ELECTRIC POWER CONSUMPTION IN SILICOMANGANESE SMELTING

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ABSTRACT

In Kakogawa Works, a ferroalloy plant was added to the existing iron and steel making plants in 1970. Since then we have been producing high-carbon ferromanganese and silicomanganese with two closed-type furnaces with capacities of 20MVA.

In Japan the cost of electric power rose suddenly after the oil crisis, and since then the ratio of power cost to product cost has increased greatly. Therefore, we have experimented with various techniques of electric furnace operation, mainly on silicomanganese production, which incurs a higher electric power cost than high-carbon ferro-manganese. We achieved and maintained a 17 percent decrease of electric power consumption of alloy (KWH/t) from 1975 to 1980.

The main reasons for this are as follows:

1) Reduction of generated slag volume per ton of alloy (slag ratio kg/t) by changing the components of the burden.
2) Improvement of the furnace operation through control of the electrode penetration.
3) Pre-treatment of raw materials with hot charging.

OUTLINE OF FERROALLOY SECTION

In Kobe Steel Ltd. both Kakogawa Works and Kotchi Works produce manganese ferroalloys. Low and medium-carbon ferromanganese are produced in Kotchi Works and high-carbon ferromanganese and silicomanganese are produced in Kakogawa Works. All of the products are provided for Kobe Steel consumption.

Kakogawa's ferroalloy plant is located within the iron and steel making plant, so its merits and distinctive features are the following:

(1) Since raw materials can be delivered by ship directly to the ore and coal wharf equipment, freight costs are reduced.

(2) By-products can be used in other processes, for example,
  - silicomanganese slag is used for the blast furnace
  - the dust from the blast furnace is used for manganese sintered ore

(3) Several plants can use electric power from a single power plant in Kakogawa which in turn utilizes gas from the electric furnace.

(4) It is possible for the ferroalloy plant to use constant load of electric power, while on the other hand the load can also be adjusted more easily than that of the other plants. Therefore, the power consumption of the entire Kakogawa Works can be adjusted by way of the ferroalloy plant.

(5) Because products are used in the neighboring steel-making plant, the cost of transportation is reduced.

(6) Since the maintenance of equipment and analytical work and administration can be done in common, it is possible to save labor and to reduce production costs.

PRODUCTION OF MANGANESE ALLOYS

Fig. 1 shows the production of manganese alloys in Kobe Steel at Kakogawa and Kotchi Works from 1975 to 1980. Though low and middle-carbon ferromanganese are produced at Kotchi Works, the silicomanganese for them has been produced at the Kakogawa plant since 1978. This chart shows a reversal in 1979 of the amounts produced of high-carbon ferromanganese and silicomanganese.

ACTIVITIES FOR THE REDUCTION OF ELECTRIC POWER CONSUMPTION

Recently the cost of electric power has risen sharply, bringing the share of power cost in the product cost of silicomanganese to half. Because of this we have performed some experiments aimed towards a reduction in electric power costs.

The task of reducing power consumption involves distributing heat energy to the best advantage and reducing loss of the energy, which is provided in the form of electric power to the electric furnace. We can achieve these purposes most efficiently by reducing slag and energy lost with gas taken out of the furnace.

In practical terms, reducing power consumption can be achieved through effective reduction of materials in the furnace by carefully selecting raw materials, combining them and by improving the electric furnace operation. Through these measures, it becomes possible to reduce the slag ratio, the outlet gas volume and minimize unnecessary temperature increase. All of these measures reduce energy loss.

In addition, charging hot sinter burden into the furnace increases input energies, therefor reducing the need for electric power. We had adopted these measures to reduce electric power consumption.

CHANGES IN POWER CONSUMPTION

Fig. 2 shows the changes in electric power consumption at Kakogawa plant with the institution various improvements. The chart also shows the changes in the slag ratio, which have a strong correlation with the power consumption.

STEPS FOR THE REDUCTION OF ELECTRIC POWER CONSUMPTION

1) Furnace operation with low volume slag ratio and increase of electric power used from tap to tap.

It is theoretically possible to operate with scarcely any slag generation in silicomanganese production. It requires the proper selection of raw materials for increased silicon recovery, since silicon is contained in both metal and slag. If the silicon recovery increases, the volume of input lime which is needed to control the slag viscosity can be decreased. We control slag viscosity by slag basicity, i.e., CaO/SiO_2 or $(CaO+1.4MgO)/(0.2Al_2O_3+SiO_2)$. Manganese in the slag is equilibrated with slag basicity. In consequence the slag volume is decreased. By adopting a method of furnace operation with a low slag ratio, we have been able to reduce the slag volume from 1200 kg/t in the past to 750 - 800 kg/t.

To gain higher silicon recovery, since 1974 we have tried to reduce the input volume of calcium oxide in the burden. Fig. 3 shows the relation between silicon recovery and CaO content in the burden, as measured in the actual monthly production in our plants. In examining the influence of CaO and MgO on silicon recovery, we recognized that CaO had a better correlation than MgO plus CaO. The correlative coefficient was 0.873 with the influence of raw materials and conditions of furnace operation, i.e., power load, electrode A/V and so on.

The manganese yield increased sharply, while on the other hand the electric power consumption did not decrease in proportion to the slag ratio. One of the reasons for this is that the slag volume at tapping had been reduced, so slag was not forced out smoothly from the furnace, causing bad furnace conditions. Another reason was that an excess of coke in the burden caused a high electrode tip position and surplus reduction of the slag. This also caused a change for the worse in the furnace conditions. Therefore, we installed more metal treatment equipment, and increased electric power consumption from tap to tap to

1.5 times the previous level. In addition, the ratio of coke in the burden was reduced. As a result of these two measures, slag in the furnace could be tapped out smoothly, and the electrode tip position went down adequately. In considering the cause of smooth slag-tapping with increased electric power consumption from tap to tap, we have focussed on these two points:
(a) the increase of heat capacity in the furnace
(b) the increase of slag and metal pressure in the furnace
From this, we were able to obtain the beneficial effects of slag ratio reduction on electric power consumption. Fig. 4 shows the progressive changes of the slag ratio and power consumption.

2) Control of the electrode penetration.

The electrode tip position (also it means the distance from the furnace bottom to the electrode tip) is one of the most important factors in operating the electric furnace, which converts the electric energy running through the tip of the electrodes submerged in the burden to heat energy. An adequate electrode tip position distributes this energy to smelting and reduction in a well-balanced way. However, we presently do not have the technical methods which would measure and control the electrode tip position correctly. The reasons for this are the following:

i) There are many factors which make the electrode tip position change.
ii) From these factors is difficult to select the most effective.
iii) It is difficult to measure the electrode length accurately in the daily operation of the furnace.

However, we judge the state of the furnace conditions from various daily phenomena and take action for the control of the electrode penetration on the basis of these observations. Fig. 5 shows the procedure in the event of unusual electrode penetration.

From another point of view, the most suitable position of electrode penetration differs with the kind of product, operation power loads and so on. We have found suitable degrees of electrode penetration through test operation and analysis of the daily furnace operation. Mainly we adjust electrode penetration according to increase or decrease of coke in the burden.

3) Control of the electrode tip position from tap to tap.

Since reduction is more important than smelting in the silico-manganese manufacturing process, it is important to have stable movement of the electrode tip position from tap to tap in order to have a stable reduction zone in the furnace and maintain high reduction efficiency. Until August of 1980, we had been operating the electric furnace automatically or manually with a constant value for the electric current in the electrodes. When the electrodes rise and fall individually from the middle period of tap to tap, it becomes what we call an unstable state. Fig. 6 shows an example of electrode tip movements. These states in which the electrode tip position is constantly moving up and down are not desirable for forming stable reduction zone in the furnace. Accordingly, we have adopted a method of electrode operation of rising by degrees, corresponding to the volumes of metal and slag which are being made in the furnace. Fig. 7 shows an example of this.

We have operated the furnace with an initial program for a rising electrode position, except in the case of abnormal electric currents of the electrodes, i.e., when the electric currents exceed the limits or when the electric currents drop less than the setting values.

The effects of this type of electrode operation are seen in the change of components and in the temperature of the furnace gas. Fig. 8 shows an example of the change in percentage of hydrogen in the outlet gas from tap to tap. As can be seen in Fig. 8, by this method we were able to obtain decreases in density and fluctuation.

Hydrogen in the outlet gas from the furnace is generated mainly by the reaction of the water in the burden and the carbon in the cokes in a high temperature zone. For that reason, the stability of the reduction zone can be judged by the concentration and the state of fluctuations of hydrogen in the furnace gas. The operation records improved with a 3.7% increase in silicon recovery and a 7.4% decrease in electric power consumption, compared with the former rates.

4) Furnace operation at 600 kg-slag/t.

After having achieved an improvement in electric power consumption, we tried operation at 600 kg-slag/t level, while the former slag level was 700 kg-slag/t. With the aim of reducing the slag ratio, we tried operation at 600 kg-slag/t for a short period in 1975, but were not able to obtain good results without disturbing the furnace conditions. The furnace conditions tend to be disturbed with slag level operations lower than 700 - 800 kg-slag/t. This is because a shortage of reduction occurs with a lack of coke or other factors, slag condition easily grow worse and the slag is not forced out smoothly from the furnace, because of low CaO level in the burden. We have been able to operate with low slag level (600 kg-slag/t) with the following items as the background.

(1) Control of the electrode penetration.
(2) Control of the electrode tip position from tap to tap.
(3) Increase of the amount of electric power used from tap to tap.
(4) Control of the slag components by adding surpentine.

5) Furnace operation using sintered ore.

As mentioned, the minimum slag volume operation has merits for high manganese recovery and low electric power consumption, from the point of view only silicomanganese operation. The minimum slag operation involves decreasing the use of ferromanganese slag for silicomanganese production. But, from the point of view both silicomanganese and high-carbonferromanganese, utilization of ferromanganese slag becomes the most important point if there is no way of the utilization except for silicomanganese materials. In this case the total merits must be balanced. If the ratio of ferromanganese slag which is used for silicomanganese materials increases, other measures should be taken for limiting electric power consumption. In our work, all of the ferromanganese slag has been used for silicomanganese production. Because the ratio of high-carbon ferromanganese to silicomanganese a little in 1980, the high-carbon ferromanganese slag ratio in the silicomanganese materials increased. Therefore, for the purpose of saving electric power and increasing productivity, we have begun to use the sintered ore with a hot charging method. As the result of using hot sintered ore of 400 - 450°C by 45 - 70% in the burden, we obtained an improvement of 150 KWH/t compared with the operation of the same slag ratio of the raw burden. Fig. 9 shows the relation between power consumption and the slag ratio.

CONCLUSION

We have applied the abovementioned improvements in electric power consumption directly in our plant, so many of them have not been studied theoretically in the laboratory. We intend to continue our work in this area as long as the production of ferro-alloys continues. For this purpose we intend to concentrate on the following:

1) To strive for a lower slag operation.
2) To develop a system for the control of electrode penetration.
3) Increased pretreatment of raw materials.
4) Effective utilization of the specific heat of exhaust-gas, metal and slag.

ACKNOWLEDGMENT

In conclusion, we thank for the parties concerned for giving us a chance to make this presentation and we hope this paper is useful to others.

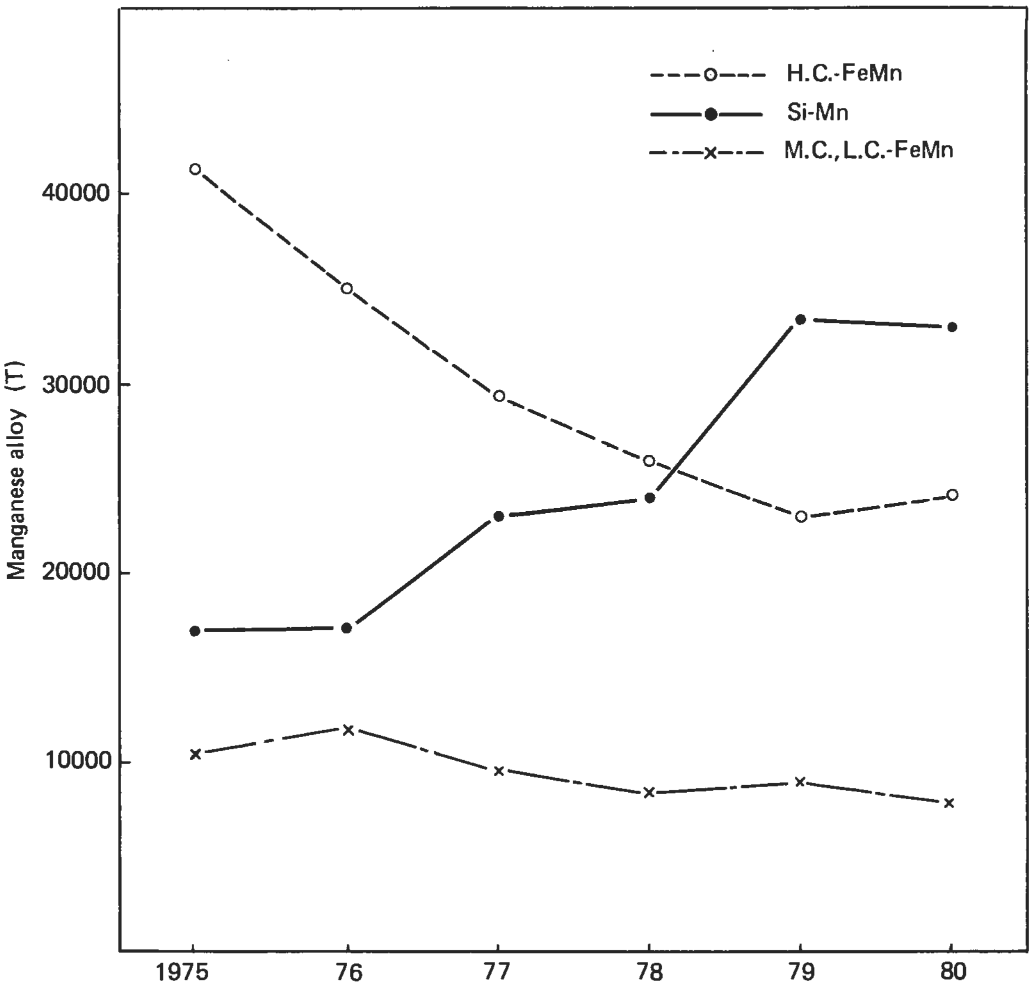

Fig. 1. Production of manganese alloys at Kobe Steel

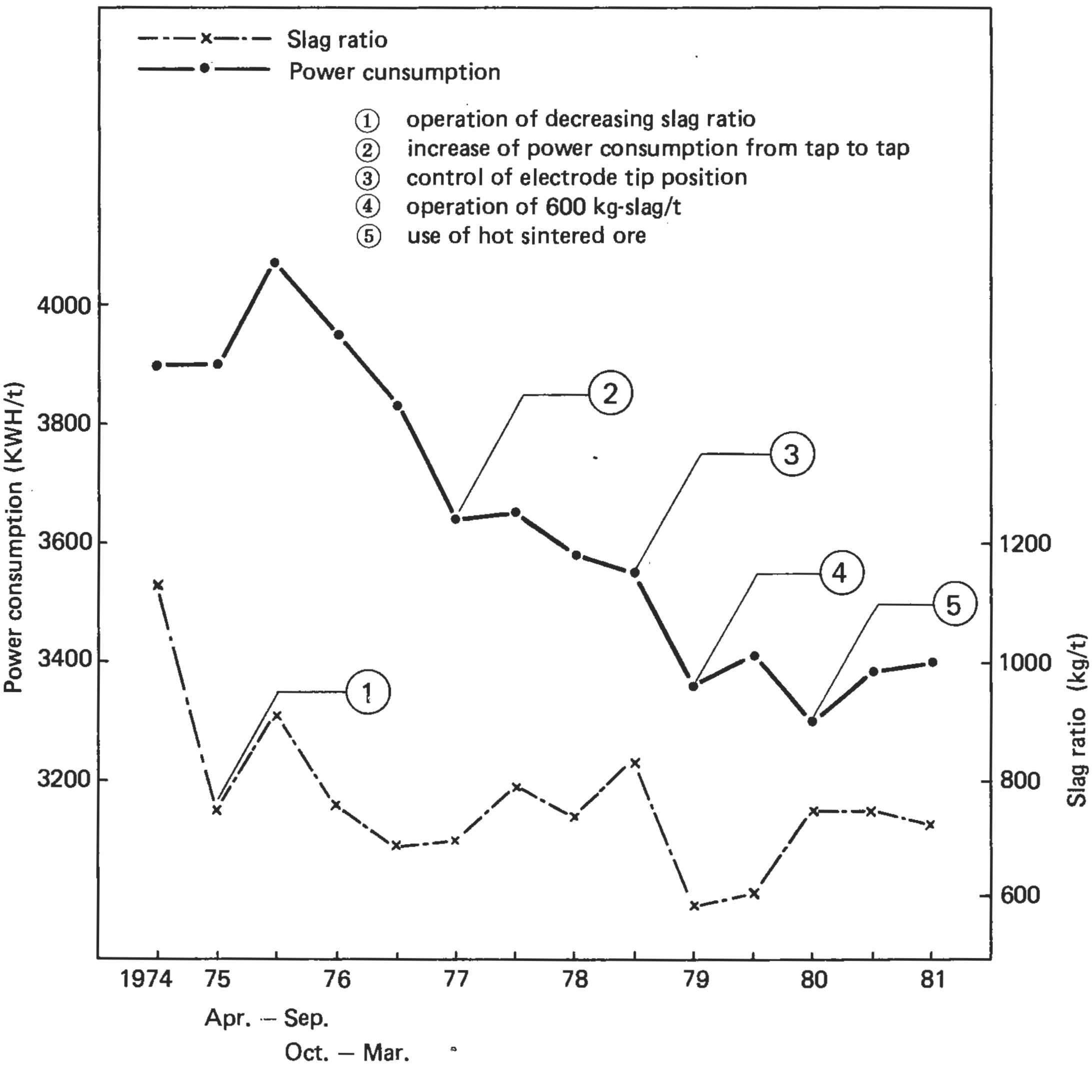

Fig. 2. Change of power consumption and slag ratio in Kakogawa plant

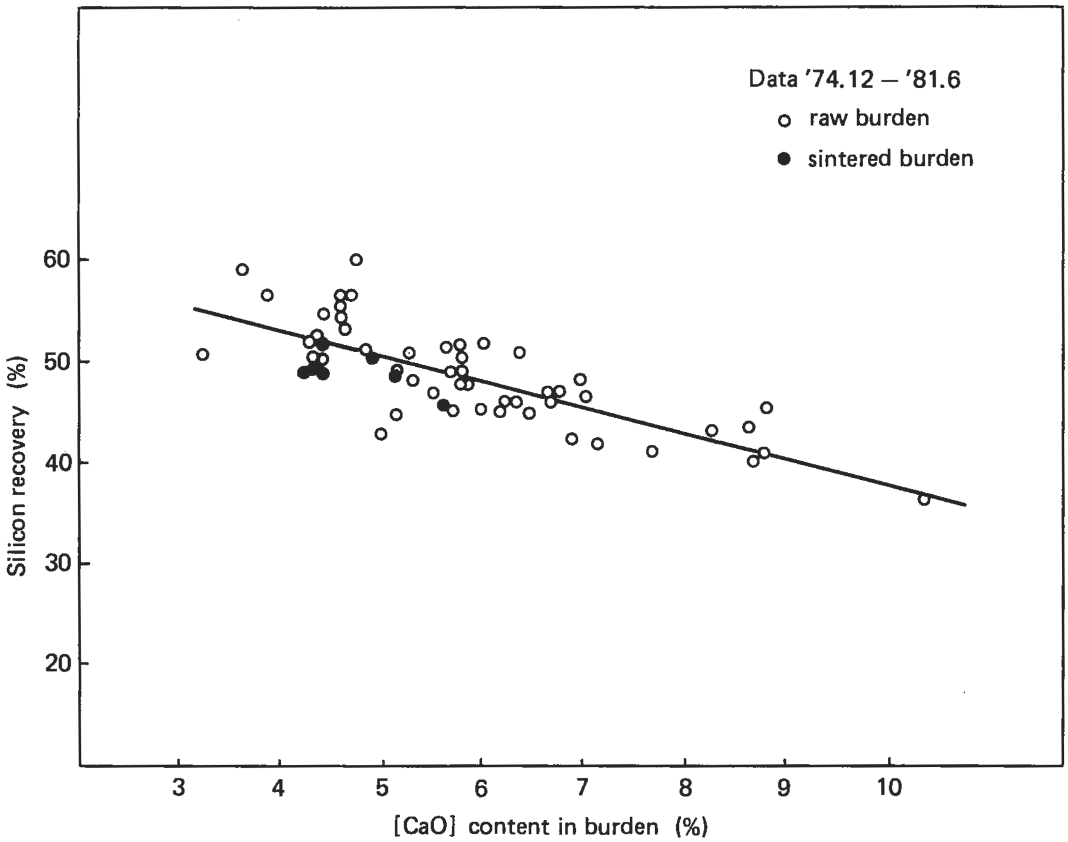

Fig. 3. Relation between CaO content in burden and silicon recovery

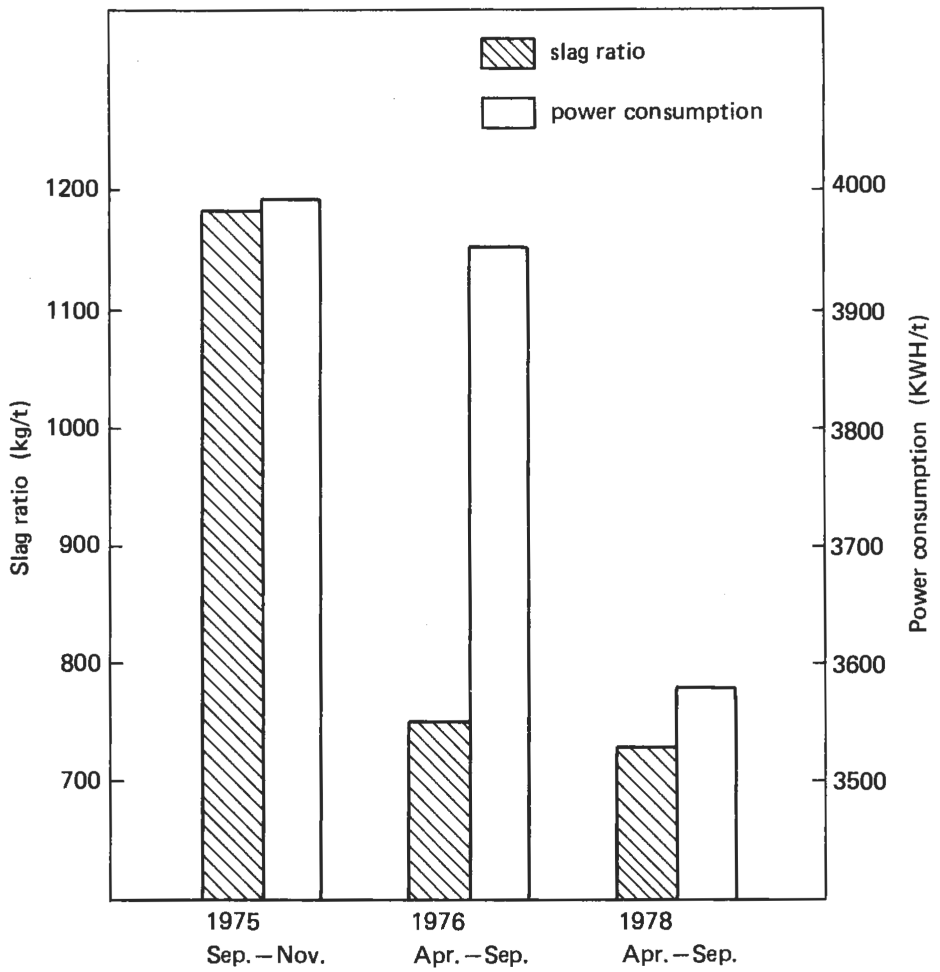

Fig. 4. Changes in slag ratio and power consumption

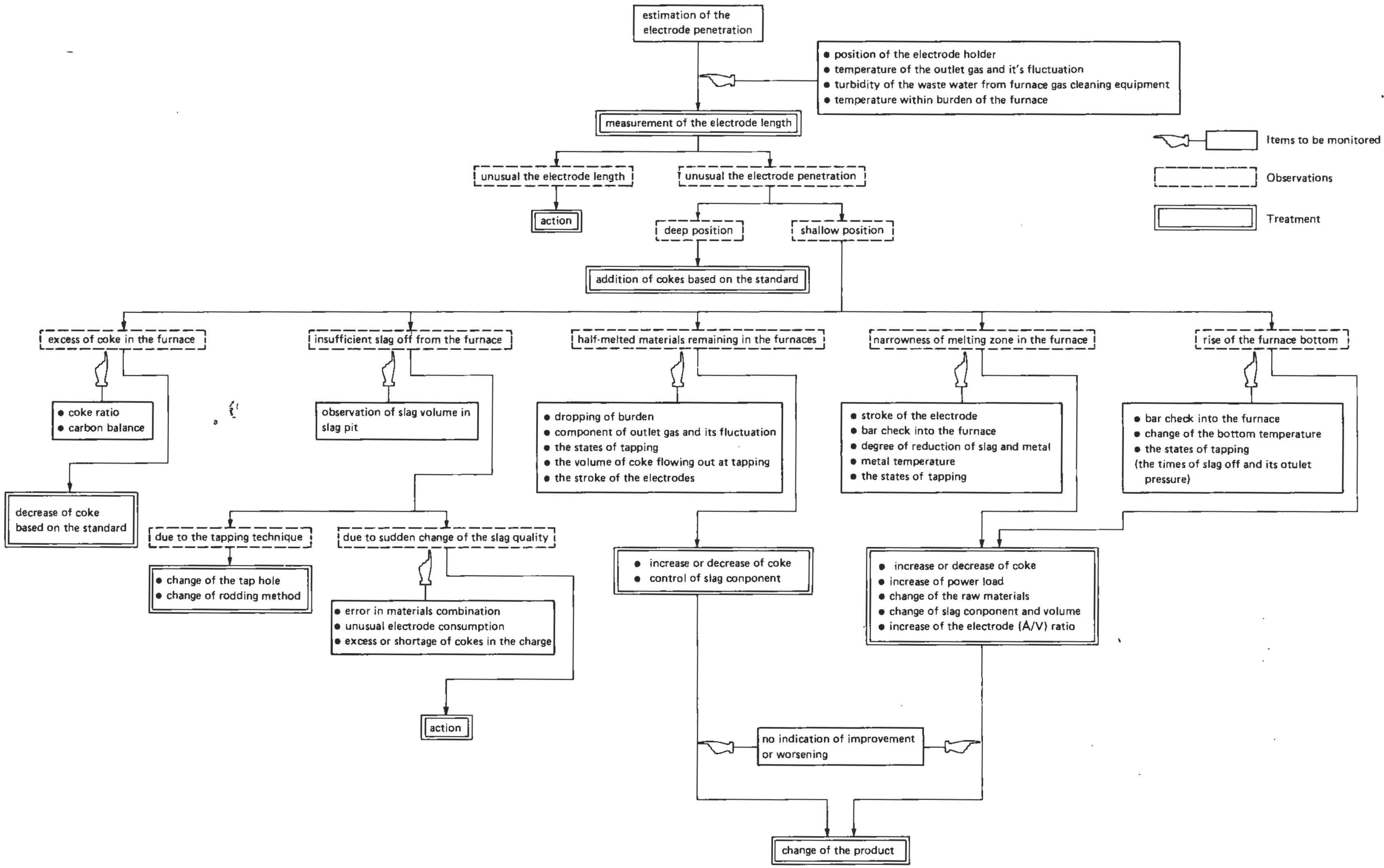

Fig. 5. Flow of action with unusual electrode penetration

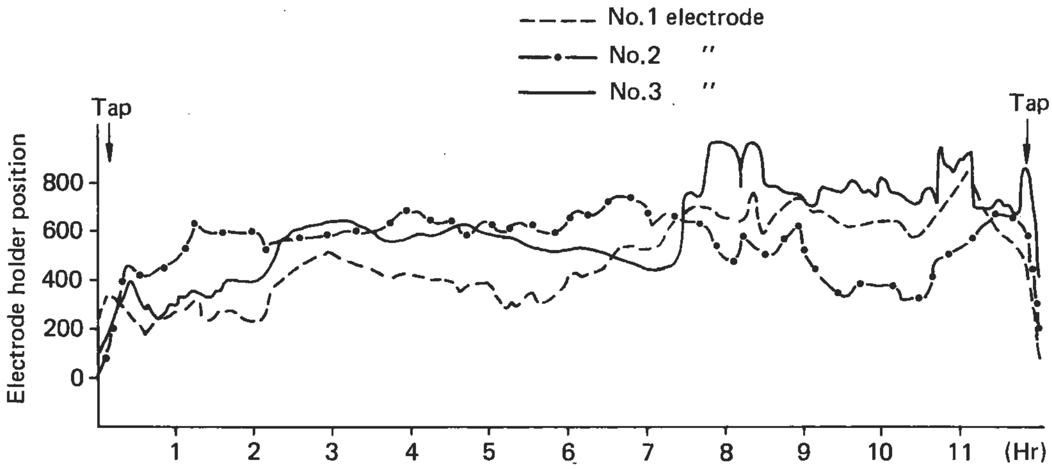

Fig. 6. Movement of electrode tip position with automatic operation

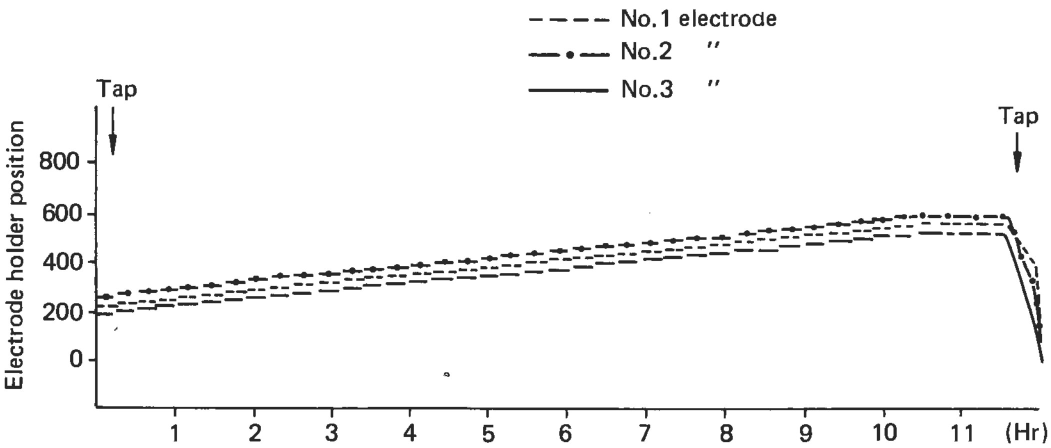

Fig. 7. Movement of electrode tip position with manual operation

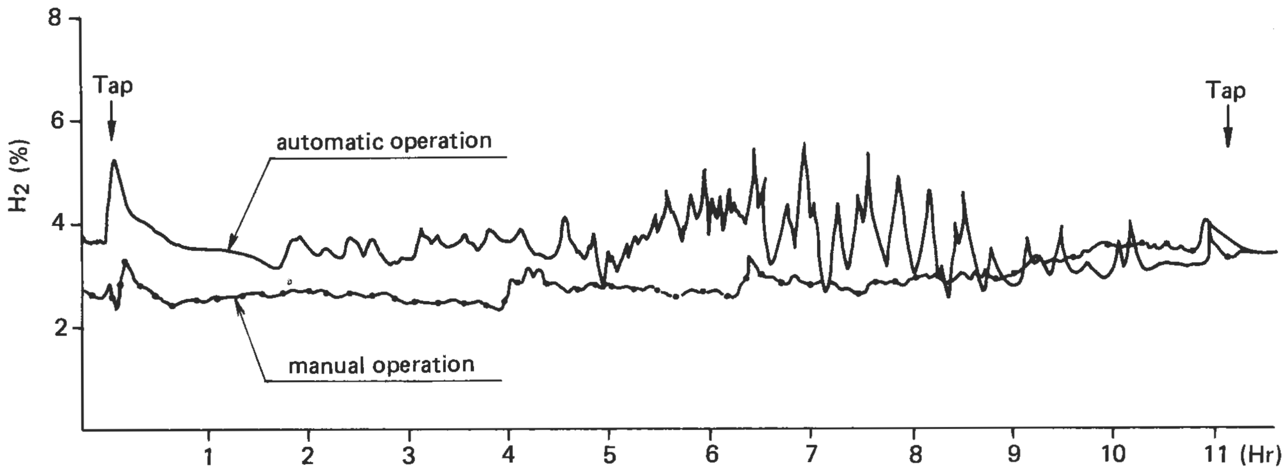

Fig. 8. Change of hydrogen in outlet gas

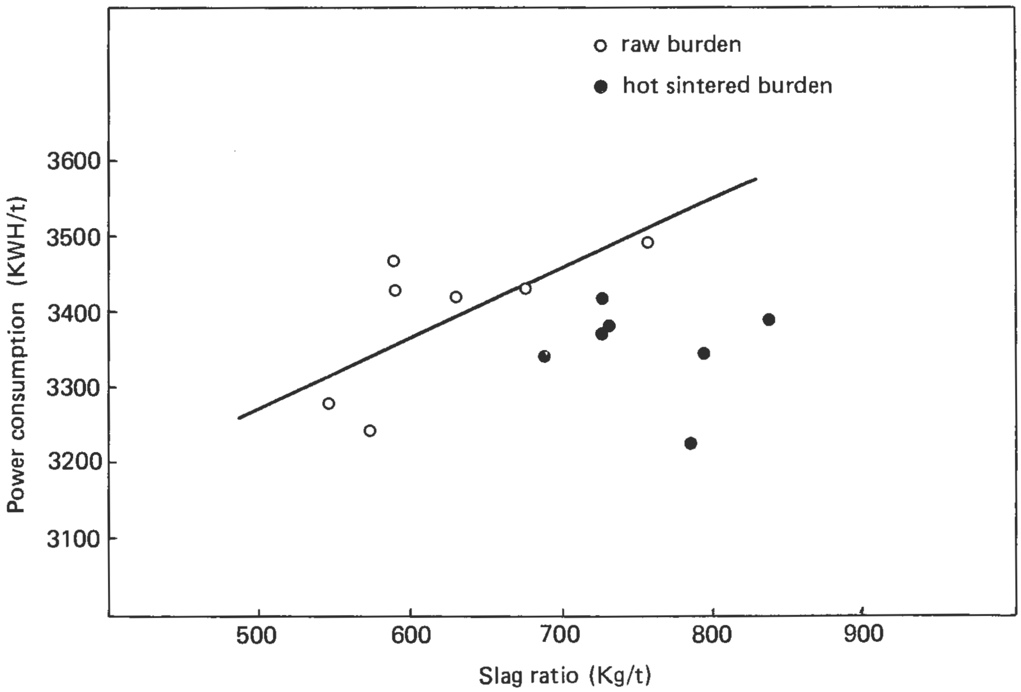

Fig. 9. Relation between power consumption and slag ratio