

MODIFICATION OF OPERATING PARAMETERS FOR FERROALLOY ELECTRIC FURNACES TO ALLOW EXTENSION OF INTERVALS TO TAP

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INTRODUCTION

The working environment in the steelmaking industry is still represented by high-temperature heavy-load work in ironmaking and steelmaking shops, and cannot be said to be as good as that in other industries. However, in order to cope with aging labourers and apply brakes on the tendency of young workers to avoid the iron and steel industry, steelmakers have been actively involved in mechanization and equipment improvement, and the working environment has been gradually improving. The Kobe Steel's ferroalloy shop has introduced various streamlining techniques and mechanized and improved equipment at the time of relining of the No. 2 electric furnace from the standpoint of improving the working environment. Recently, to move one step further, night shifts have been reduced to improve working conditions.

FERROALLOY MANUFACTURING FACILITIES

The ferroalloy shop of the Kakogawa works produces about 70,000 tons of high-carbon ferromanganese (FeMnH) and silicone manganese (SiMn) annually, and possesses a Dwight-Lloyd sintering machine, 2 units of closed type electric furnaces with 20,000 kVA transformer capacity, and product processing equipment to crush and screen products. In order to improve the sintering yield and save energy, sinters are not sieved with screens but are all hot-charged into electric furnaces. The material charged into the electric furnaces is reduced and melted with coke, and metal is guided to a casting machine, where crushing and screening take place to a specified particle size after cooling. Figure 1 shows the product manufacturing flow.

OPERATION RESULTS

Figure 2 shows the change of furnace operating condition resulting from extended intervals to tap. Since October 1992, electric power consumption per tap has gradually been increased from 90,000 kWh, but when it achieved around 140,000 kWh, slip and sudden rise of gas temperature began to occur. To counteract these phenomena, the basicity was lowered with slag viscosity and high-temperature properties of sinter taken into account, and the slag volume was lowered from 500 kg/t to 400 kg/t level. To stabilize and increase electric resistance, ore-coke mixed charging and small-size coke (6-8 mm) were decided to be

adopted. As a result, electric power for melting was able to be reduced by about 100 kWh/t and the Mn yield was improved by about 5%. Implementing these countermeasures, the metal volume per tap was able to be increased from 45 tons to 90 tons. During the test run of nearly one year, smooth furnace conditions were generally achieved without any serious trouble, and the number of casts per day was reduced by half, from 4 times per day to twice per day, thereby zeroing tapping operation in night shifts.

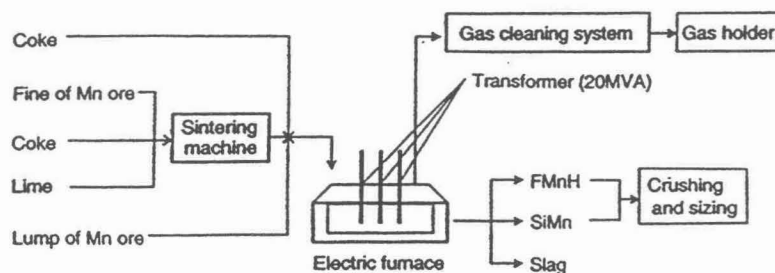


Figure 1. Process flow of FeMnH, SiMn.

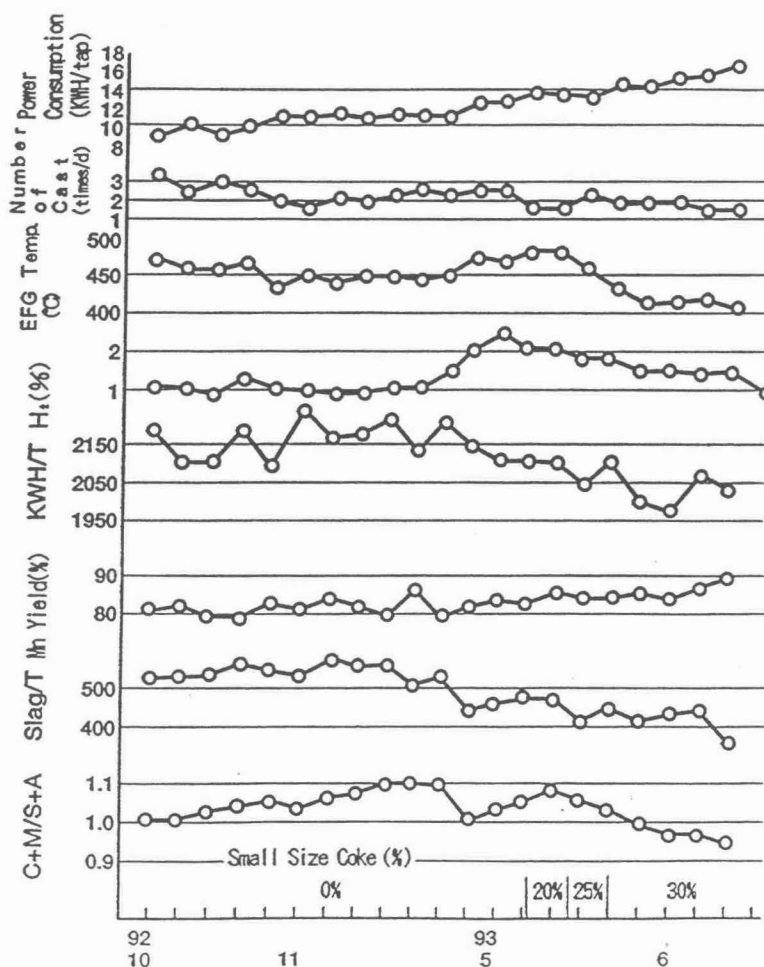


Figure 2. The change of furnace operating conditions.

DISCUSSION

Concept of extension of intervals to tap.

In order to extend intervals to tap, hot metal must be retained in an electric furnace as much as possible.

When a large volume of slag/metal collects in the furnace, electric resistance at the hearth lowers. As a result, the electrode tip end gradually rises but excessive rise of the electrode tip end degrades furnace operating conditions, causing channelling, slip, fluctuation of furnace pressure, etc. Consequently, countermeasures were designed for extending intervals to tap, with the following designated as priority problems:

1. Minimizing slag volume accumulated in the furnace within one tap.
2. Increasing electric resistance at the hearth and holding the electrode tip end as deep as possible.

In reducing the slag volume, basicity was reduced stepwise, with slag viscosity, Mn yield, and sinter properties taken into account. Because the position of the fusing cohesive zone in the furnace has close connection with the electrode tip end position, high-temperature load tests were carried out for determining properties of sinters as well as grasping changes in their high-temperature properties. In order to increase electric resistance at the hearth, coke of the particle size small enough to prevent hindrance to permeability in the furnace is used to increase contact interfaces between coke particles.

Reduction of basicity of Mn sinter and high-temperature properties.

It has been determined by dissecting real furnaces that the fusing cohesive zone exists in electric furnaces as observed in blast furnaces. Because the position of the fusing cohesive zone in the furnace is closely related to the direct reduction area, electric resistance, and other factors, it can be said that furnace operating condition is better when the fusion cohesive zone is located as deep in the hearth as possible. From this viewpoint, as an evaluation of electric furnace burdens, high-temperature load tests are carried out under electric furnace gas conditions, the results of which are shown in Figure 3. Ore B has not only high melt-down temperature but also narrow cohesive zone width of ore and provides excellent high-temperature properties, while ore A has a wide cohesive zone width with low softening temperature but conversely high melt-down temperature.

The test results using these ores indicate that ore A raised gas temperature and caused poor furnace operating condition, and also increased the electric power consumption rate. Based on these results, burden materials to electric furnaces have been improved to achieve the properties nearly equivalent to those of ore B.

In the present experiment, the basicity ($\text{CaO} / \text{SiO}_2$) of burdens was decreased as a mean to reduce the slag volume, which was carried out stepwise with utmost care to prevent degradation of furnace operating conditions, while making sure of effects of basicity on high-temperature properties. Figure 4 shows the results, lowering the basicity less than 0.82 causes

very high pressure drop, so high-temperature properties of charging material become worse by lowering basicity extreme.

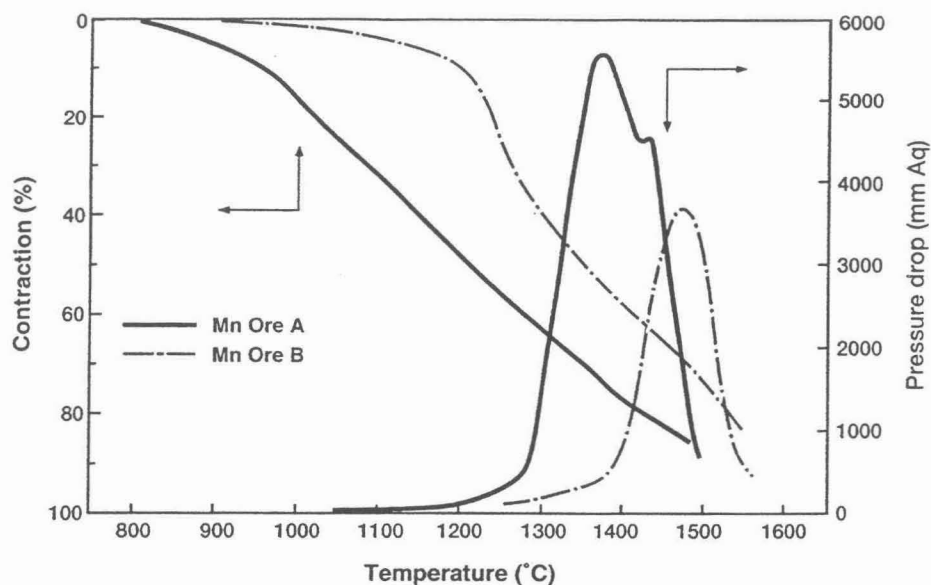


Figure 3. High temperature properties of Mn ore under load.

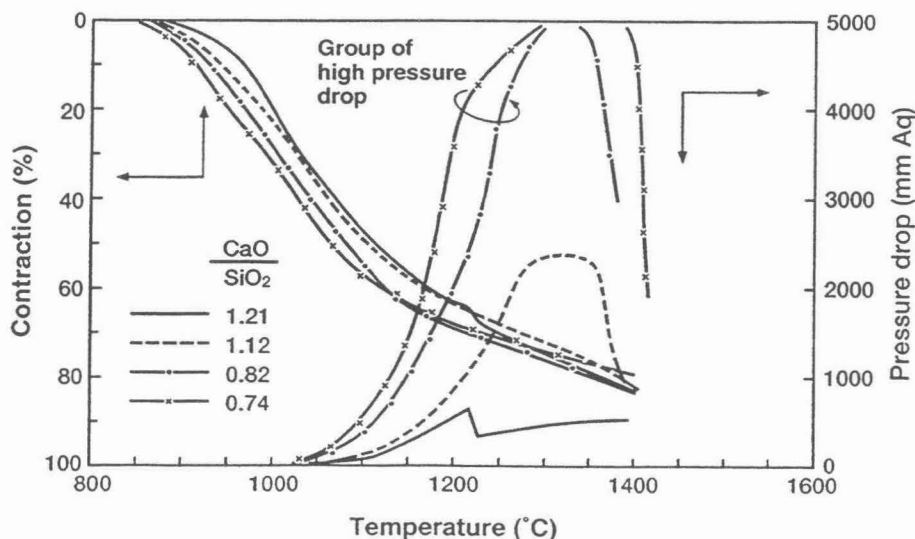


Figure 4. Effect of basicity on high temperature properties of Mn sinter.

Ore-coke mixed charging.

Figure 5 shows the material charge ratio for each electrode before and after mixed charging was carried out. Before mixed charging was carried out, fluctuation of the charge ratio between electrodes was great. However, when mixed charging is carried out, the charge ratio of each electrode is converged to the ideal 33% range and becomes uniform. It is assumed that in stratified charging, every time coke and ore are charged to each electrode alternately, electric resistance varies greatly, affecting the electrode consumption rate, etc. and generating

difference in number of charges, but in mixed charging, uniformly mixed ore and coke are charged to all electrodes, stabilizing electric resistance and alleviating charge fluctuations between electrodes.

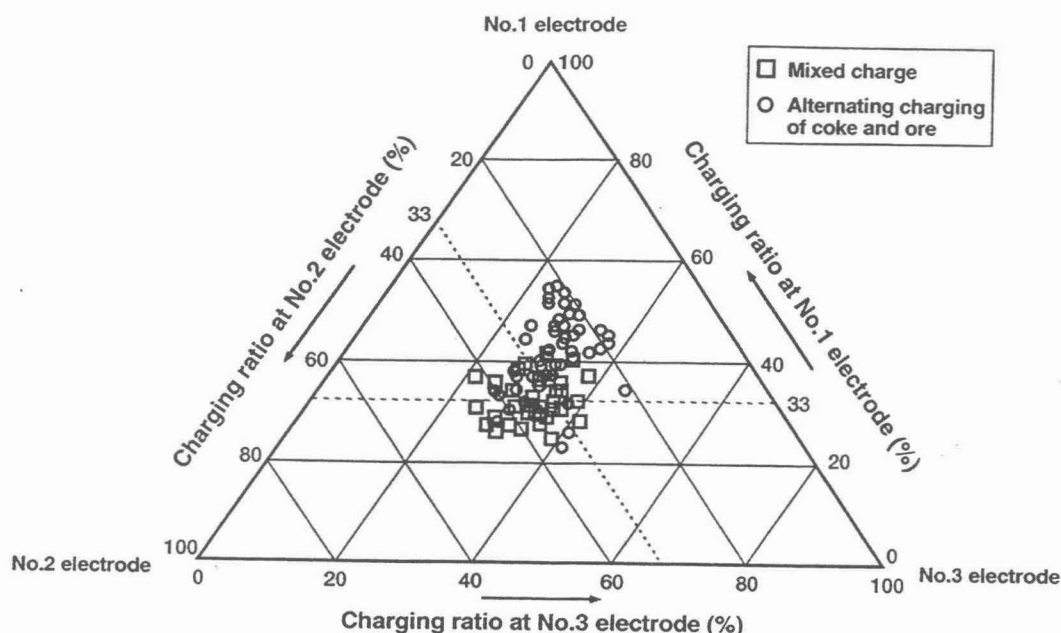


Figure 5. Effect of mixed charge ore charging ratio at each electrode.

Effects of the use of small-size coke.

1. Measurement of electric resistance by coke size.

In order to determine the effects of small-size coke in the furnace, the relationship between coke size and electric resistance was investigated. Figure 6 shows the results, which indicates that as the mean particle size decreases, electric resistance increases. It is assumed that because electric resistance depends on the number of contact interfaces between particles, the contact interfaces between particles may have increased as particle size decreases. In addition, mixing small-size coke with conventional sizes increases fluctuation of resistance and the effect of coke particle size on resistance decreases as compared to that of single-size particles. It is assumed that mixing would increase the range of coke particle size, generate fluctuation in resistance and possibly suppress the effects of small-size coke.

In general, it is known as silo characteristics that when the silo level is high, the particle size is small, and conversely, when the silo is located at a low level, the particle size increases. Since in actual operation these fluctuations have great effects on resistance, coke is weighed and discharged from a multiplicity of silos to restrict fluctuation in particle size. Figure 7 shows a schematic representation when simultaneous weighing and discharging were carried out with a multiplicity of silos and the results of particle size fluctuation at that time. It indicates that uniform particle size is achieved by weighing and discharging from a multiplicity of silos located on high and low levels than in the case of a single silo. For one of the priority control items for future operating control, the control of silo level has been further reinforced.

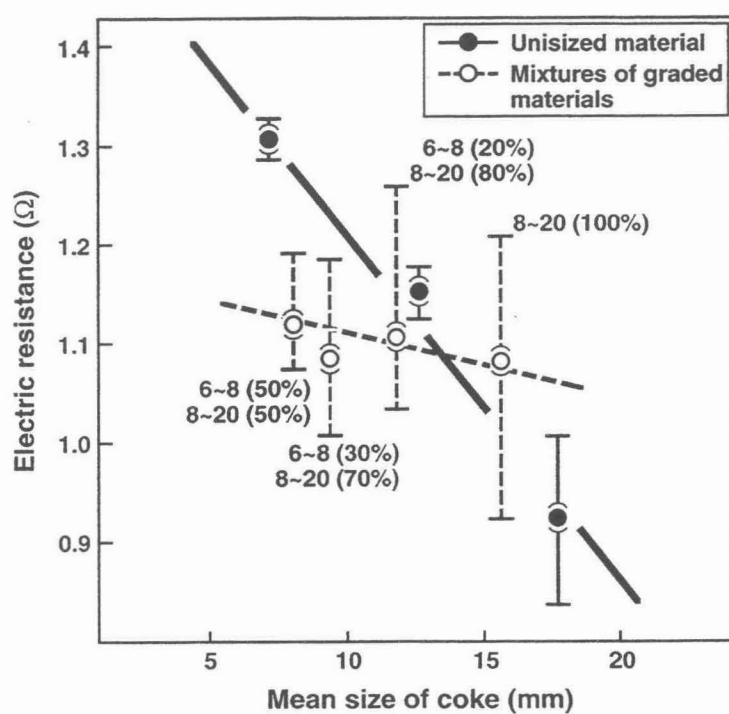


Figure 6. Effect of mean size of coke on electric resistance of unisized materials and mixtures of graded materials.

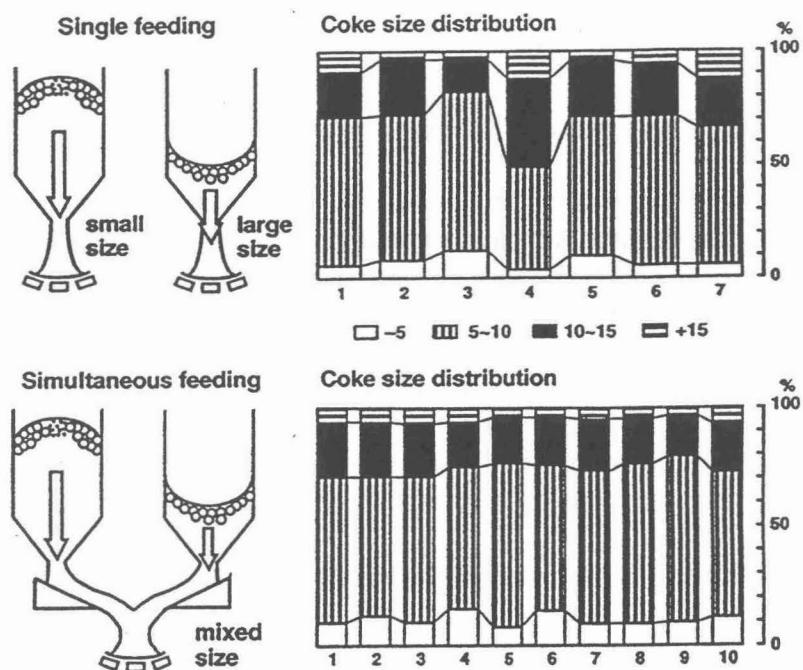


Figure 7. Comparison of size distribution of coke between single feeding and simultaneous feeding.

2. Effects in actual furnaces

Figure 8 shows the relationship between the electric power consumption rate and electrode movement over one tap. The electric furnaces of the Kakogawa Works have resistance control, and in general, as the working power increases, slag and metal stay in the furnace, causing electric resistance at the hearth to lower, and the electrode position moves to the furnace top where electric resistance is high, increasing the electrode stroke. However, when small-size coke is charged in the furnace, the electrode stroke does not increase even if working power reaches 140,000 kWh or over. This is attributed to high electric resistance at the hearth achieved by charging small-size coke, and resistance does not decrease as observed conventionally.

Figure 9 classifies the relationship between slag basicity and %Mn in slag by small-size coke mixing rates. As small-size coke is mixed more than 30%, %Mn in slag lowers even at the same basicity. This is assumed that smaller particle size of coke has increased the area of reaction between Mn oxide in slag and C in coke. The use of small-size coke has enabled not only lowering of %Mn in slag but also adjusting of slag basicity, lending itself to a convenient means to improve the Mn yield.

Next, Figure 10 shows the relationship between the holder position after tapping and the melting power consumption rate. It indicated that as the holder position lowers, the power consumption rate lowers. In particular, when small-size coke is charged, the holder position further lowers, exhibiting this tendency more conspicuously. This has been brought by improved gas utilization rates ($\text{CO}_2/(\text{CO} + \text{CO}_2)$) achieved by expansion of the direct reduction zone as a result of mixing small-size coke, which has increased furnace resistance and held the electrode tip end to comparatively low hearth, and the quantity of high-order Mn oxides transferring to low-order Mn oxides has increased. As a result, heat has been effectively fed to the hearth, and the energy consumption rate has been lowered as well as that of coke and electrode material such as paste, etc. simultaneously as slag and metal reaction takes place.

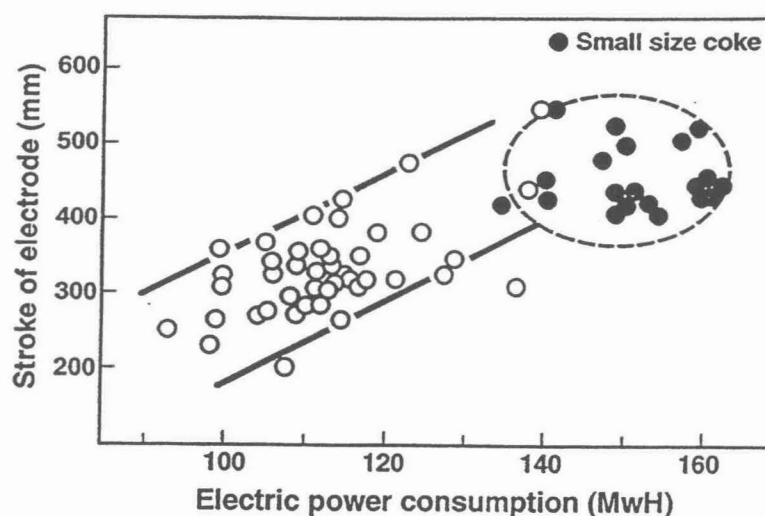


Figure 8. Relationship between electric power consumption and stroke of electrode.

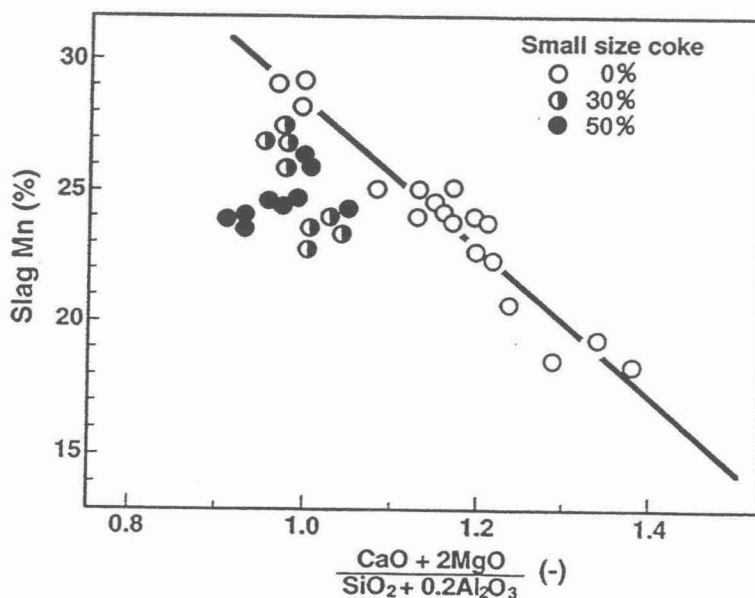


Figure 9. Relationship between slag basicity and slag Mn in various ratio of small size coke.

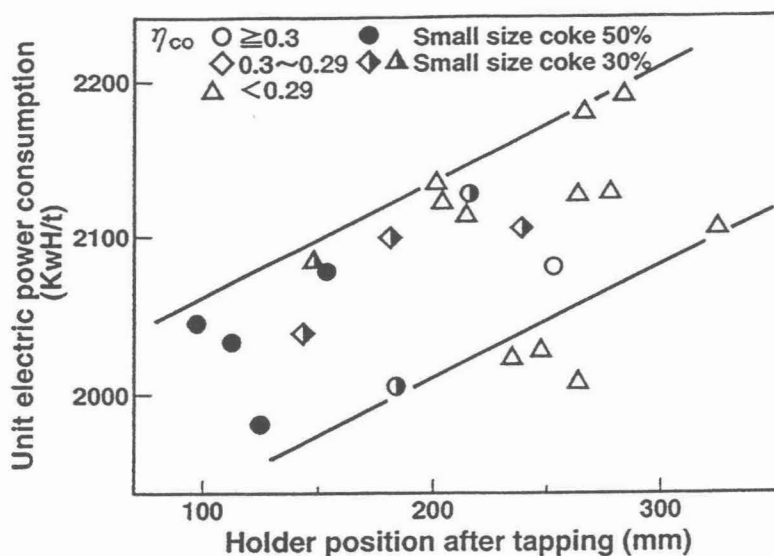


Figure 10. Relationship between holder position after tapping and unit electric power consumption in various gas utilization and ratio of small size coke.

CONCLUSION

Various measures have been carried out to extend the intervals to tap of electrode furnaces and to reduce work loads of night shifts. Among all, the use of small-particle size coke can double the intervals between taps when FeMnH is manufactured, which was our original goal and the technique for controlling electrodes has been established in ferroalloy manufacturing in electric furnaces.