KAWASAKI STEEL TECHNICAL REPORT
No.17 ( October 1987 )

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# Construction and Operation of Hot Metal Pretreatment Facilities at Mizushima Works*



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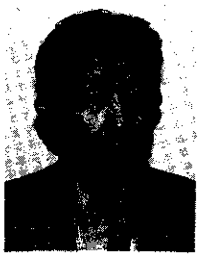
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## 1 Introduction

At the Mizushima Works of Kawasaki Steel, the double tapping process (D-Tap process) has been put into use with converters to produce very pure steels. Owing to restrictions arising from synchronized operation with the rolling mills, however, it has gradually become more difficult to increase the quantity of very pure steels with the double tapping process. Meanwhile, it is recognized that pretreatment of hot metal as an indispensable means of reducing refining costs and making maximum use of the strong stirring force of the top and bottom blown converter, and the superiority of specialized refining methods has been demonstrated.

In line with these considerations, the Works started construction of a series of hot metal pretreatment facilities, mainly for desiliconization in the runner of blast furnace and dephosphorization in the torpedo car, the facilities went into operation in March 1985. All equipment has been operating smoothly since start-up. At present, the amount of hot metal treated monthly by desiliconization in the runner of blast furnace and dephosphorization in torpedo car exceeds 220 000 t and 100 000 t, respectively. These hot metal pretreatment facilities contribute greatly to overall reduction in the costs of the specialized refining and to consistent mass production of very pure steels.

This paper presents an outline of these hot metal pretreatment facilities and of their operating conditions.

* Originally published in *Kawasaki Steel Giho*, **18**(1986)4, pp. 334-340

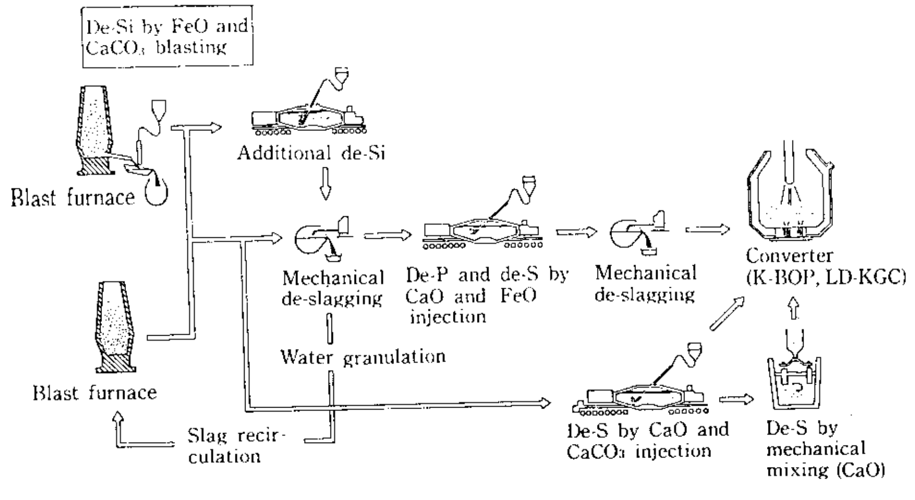


Fig. 1 Hot metal pretreatment process at Mizushima Works

## 2 Makeup and Layout of Hot Metal Pretreatment Facilities

An outline of the hot metal pretreatment process is shown in **Fig. 1**. After blasting-type desiliconization treatment in the tilting spout of the blast furnace, the hot metal is transported by torpedo car to the Hot Metal Pretreatment Center (PTC). At the PTC, first the desiliconization slag is removed by a mechanical slag dragger, then dephosphorization and desulfurization are conducted. The hot metal pretreatment at the PTC also involves desiliconization. If a hot metal has been insufficiently desiliconized in runner or is taken from a blast furnace not provided with desiliconization equipment, appropriate desiliconization pretreatment is possible at the PTC. In other words, the PTC is capable of both adjustment desiliconization to reduce the cost of dephosphorization and single desiliconization to supply low-silicon hot metal to the K-BOP converter at the No. 2 steelmaking plant. Deslagging is conducted again after dephosphorization and the hot metal thus pretreated is sent on to the converters.

After deslagging at the PTC, the slag after desiliconization is granulated by slag granulating equipment and is recirculated to the sintering plant, while the slag after dephosphorization is cooled and then dumped after the recovery of iron-bearing materials. Thus the new facilities also make possible the effective utilization of slag.

The layout of the hot metal pretreatment facilities is shown in **Fig. 2**. The desiliconization equipment in the runner is installed at the No. 4 BF, the main blast furnace of the Works, while the PTC is situated between the blast furnaces and the No. 2 steelmaking plant.

The Torpedo Car Cleaning Center (TCC) for removing hot slag from torpedo cars is arranged on the return tracks from the No. 2 steelmaking plant. This equipment can clean torpedo cars online, and prevents decreases in the hot metal capacity of the cars due to the accumulation of slag caused by hot metal pretreatment. The slag remaining in the torpedo car is completely removed at the TCC after every two or three uses of the car.

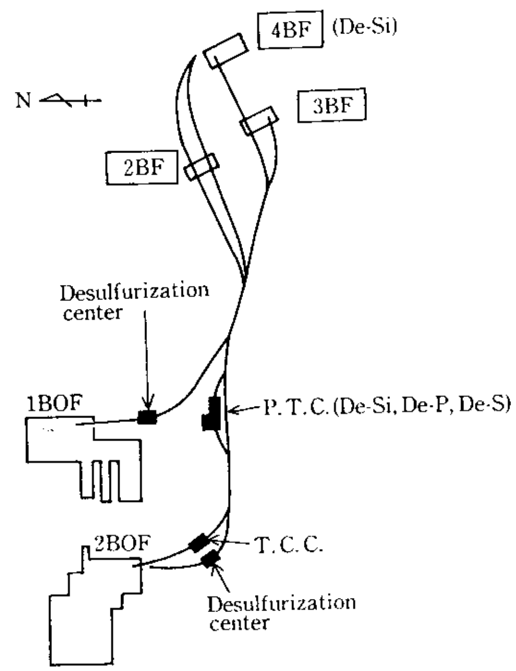


Fig. 2 Layout of hot metal pretreatment process at Mizushima Works

## 3 Specifications and Features of Hot Metal Pretreatment Facilities

### 3.1 Desiliconization Equipment in the Runner[1)]

A schematic of the equipment for desiliconization

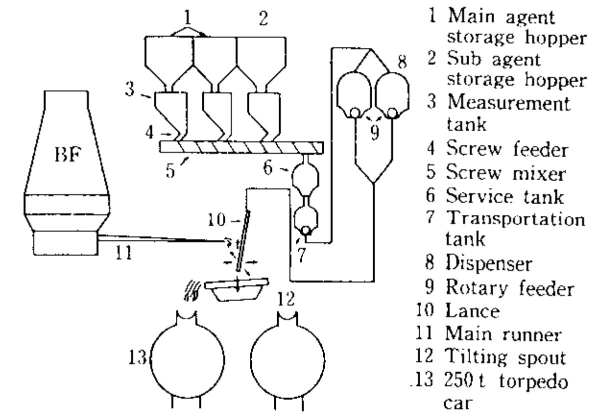


Fig. 3 Outline of desiliconization equipment[1)]

Table 1 Specifications of desiliconization equipment

| Item | Specification |
|---|---|
| Main agent | Sinter dust |
| Sub agent | $CaCO_3$ |
| Flux size | <1 mm |
| Capacity of hopper | $30\ m^3 \times 1$, $40\ m^3 \times 2$ |
| Max. injection rate | 365 kg/min |

in the runner is shown in **Fig. 3**; the main specifications of this equipment are given in **Table 1**. The features of this equipment are as follows:

(1) The blasting method, which ensures high reaction efficiencies, was adopted for the addition of desiliconizing agents. The kinetic energy of the dropping hot metal is effectively utilized by adding the desiliconizing agents to the hot metal in the tilting spout at exactly the point where the metal falls from the main runner.

(2) To permit continuous desiliconization, two dispensers were installed, making rapid switchover possible. This system ensures stable desiliconization treatment of each entire tap of hot metal. This allowed a reduction in facility investment.

(3) The series of operations including the weighing, mixing, and blasting of desiliconizing agents is fully automated and carried out by direct digital control (DDC), reducing manpower requirements.

### 3.2 Hot Metal Pretreatment Center[2)]

A schematic view of the PTC is shown in **Fig. 4**; the main specifications are given in **Table 2**. The features of the PTC equipment are described below:

(1) Because of shortening a series of operational time, the layout of this center is such that deslagging and the injection for desiliconization and dephosphorization are conducted at the same location. Moreover, simultaneous treatment in two torpedo cars is possible, eliminating potential bottlenecks in the

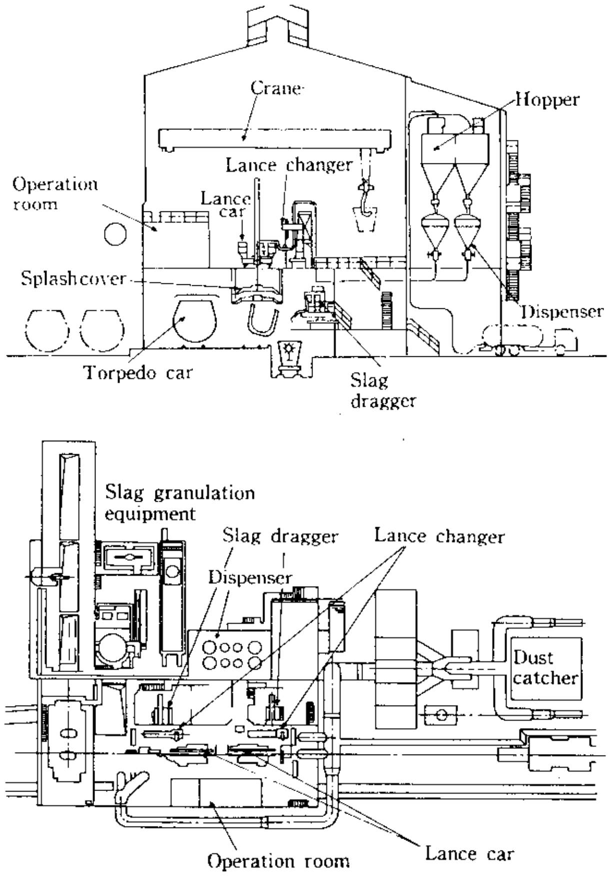


Fig. 4 Layout of Pretreatment Center for hot metal (PTC)

Table 2 Specifications of hot metal pretreatment equipment[2)]

| Item | Specification |
|---|---|
| Flux | |
| Desiliconization | Dust, lime |
| Dephosphorization | Dust, lime, flour spar, soda ash |
| Injection equipment | |
| Dispenser | 4 dispensers × 2 lines |
| Injection type | Rotary feeder |
| Method of flux mixing | On line mixing |
| Max. injection rate | 500 kg/min |
| Lance car | Double lances × 2 lines |
| Slag dragger | Mechanical dragger × 2 stations |
| Dust catcher | |
| Exhaust gas cooler | Air cooled tube type |
| Capacity | $60 \times 10^4\ m^3/h$ |
| Slag granulating capacity | 12 t/30 min |

supply of pretreated hot metal to the converter plants, even with dephosphorization, which has a long treatment time.

(2) Mechanical deslagging equipment was adopted because this type of equipment permits stable deslagging regardless of the properties of the slag.

(3) To obtain suitable composition of the fluxes to be injected in the treatment, an online mixing system was developed and adopted. All flux types can be mixed separately at the injection line. In other words, precisely the required amounts of four fluxes are measured out and mixed at the juncture of the injector pipes. This system makes equipment for premixing of fluxes unnecessary. Further, it has become possible to change flux composition for each treatment unit or in series during treatment.

(4) A slanting lance was adopted to increase the stirring force in the torpedo car and to reduce the running cost for refractories. To provide against lance problems during treatment, each lance car was equipped with two lances, thus permitting rapid replacement.

(5) Each step in the powder injection operation, i.e., powder receiving, measuring, tank pressurization, and injection, is fully automated. An inexpensive instrumentation system was installed.

### 3.3 Torpedo Car Cleaning Center[3)]

The TCC equipment is shown schematically in **Fig. 5**; the main specifications are listed in **Table 3**. The main

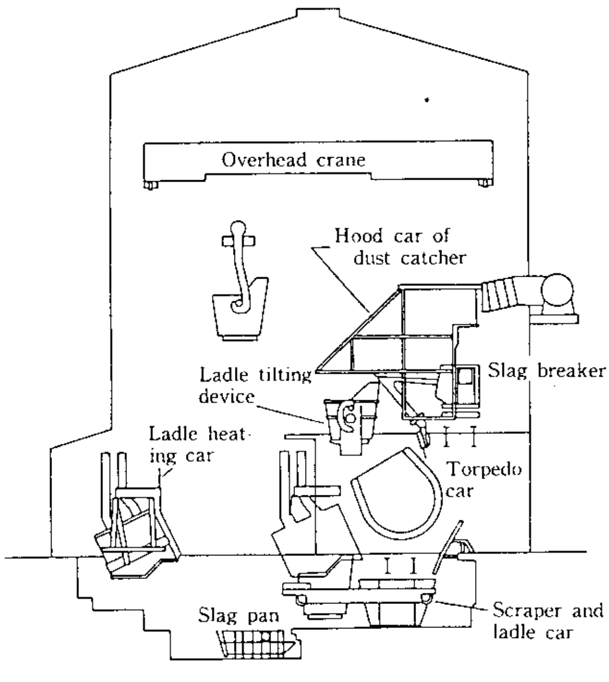


Fig. 5 Elevation view of Torpedo Car Cleaning Center

Table 3 Specifications of Torpedo-car Cleaning Center equipment[3)]

| Item | Specification |
|---|---|
| Capacity of hot metal ladle | 15 ton |
| Volume of slag ladle | 6 m³ |
| Full load capacity of hot metal ladle car | 30 ton |
| Maximum capacity of heating facilities | $80 \times 10^4$ kcal/h |

equipment is a slag breaker, ladle car with scraper, ladle heating car, and ladle tilting device.

To prevent the loss of the hot metal remaining in the torpedo car together with slag, the remaining hot metal is kept in the molten condition during the removal of hot slag and is returned to the torpedo car after completion of deslagging. This is the distinguishing feature of this TCC.

## 4 Progress of Hot Metal Pretreatment Operation

### 4.1 Transition of Amount of Hot Metal Treated

The expansion of hot metal dephosphorization at the PTC is shown in **Fig. 6**. The monthly amount of dephosphorized hot metal has recently reached 100 000 t.

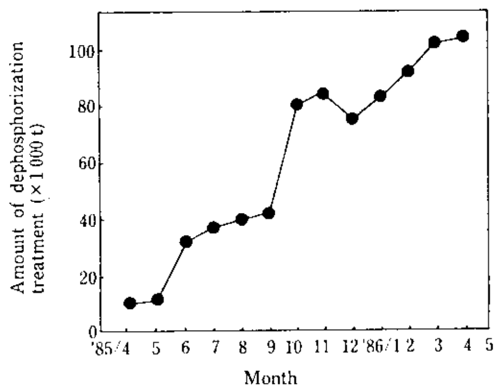


Fig. 6 Change in steel amount of dephosphorization treatment

### 4.2 Hot Metal Composition after Pretreatment

Target compositions for hot metal at various stages in the process between tapping and the converter are shown in **Fig. 7**. The present target silicon content after desiliconization in the runner is set at 0.15% so that the hot metal can be subjected either to dephosphorization or to desiliconization when intended for use in the K-BOP converter in the No.2 steelmaking plant. The feed rate of desiliconizing agents is controlled in response to the silicon content of the as-tapped hot metal and the hot metal temperature. **Figure 8** shows the

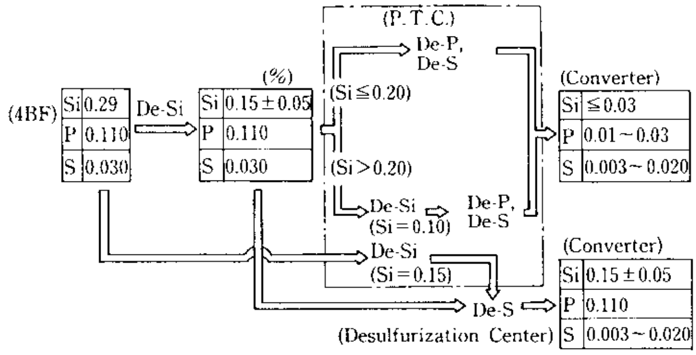


Fig. 7 Target of Si, P, and S concentrations at each process

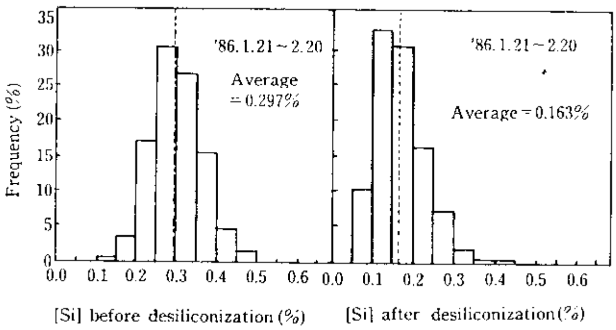


Fig. 8 Distributions of Si concentration before and after desiliconization

Table 4 Flux composition (example)

(%)

| Treatment | Sinter dust | CaO | $CaF_2$ | $Na_2CO_3$ |
|---|---|---|---|---|
| Desiliconization | 75 | 25 | | |
| Dephosphorization | 54 | 38 | 4 | 4 |

distribution of silicon content before and after desiliconization in the runner. As is apparent from this figure, silicon content is controlled with high accuracy.

When the control system for torpedo cars running between the blast furnaces and the converters is completed, a system permitting more elaborate desiliconization is to be adopted. This system will take into account whether dephosphorization is conducted and is expected to make possible further cost reductions.

In desiliconization in the runner, sinter dust is used as the necessary oxygen source for desiliconization and lime is added as a subflux. The amount of lime added is determined so that the basicity of slag after desiliconization is maintained in the range of 0.9 to 1.2 to prevent resulfurization during desiliconization, suppress slag foaming in the torpedo car, and stabilize granulation efficiency after deslagging at the PTC.

Incidentally, at the PTC the necessity of the above-mentioned adjustment desiliconization is decided before the treatment according to silicon content, and the dephosphorization is then conducted. With the hit ratio of silicon content after desiliconization in the runner improving, however, the amount of hot metal requiring adjustment desiliconization is gradually decreasing. Adjustment desiliconization is presently conducted in about 30%.

Target phosphorus and sulfur contents after dephosphorization at the PTC are determined in accordance with the specifications of the heat as given by the converter which uses dephosphorized hot metal. The flux blending ratio and blowing pattern suited to these values are selected.

The maximum possible flux injection rate in desiliconization and dephosphorization is 500 kg/min. The dephosphorization treatment time is 20 to 30 min.

Representative examples of flux composition for desiliconization and dephosphorization are shown in **Table 4**. Sinter dust is used as the necessary oxygen source for desiliconization and dephosphorization, and slag basicity is adjusted using burnt lime. In dephosphorization and desulfurization, about 4% fluorspar is added to accelerate slag formation and about 4% soda ash is added to improve desulfurization efficiency.

Typical flux injection patterns in dephosphorization are shown in **Fig. 9**. Changes in hot metal composition with these injection patterns are shown in **Fig. 10**. Pattern 1 is intended for application to the production of low-sulfur steels. In this pattern, desulfurization is conducted by injecting burnt lime and soda ash before dephosphorization. After the sulfur content of hot metal reaches the target value, dephosphorization is conducted while resulfurization is suppressed. Using this pat-

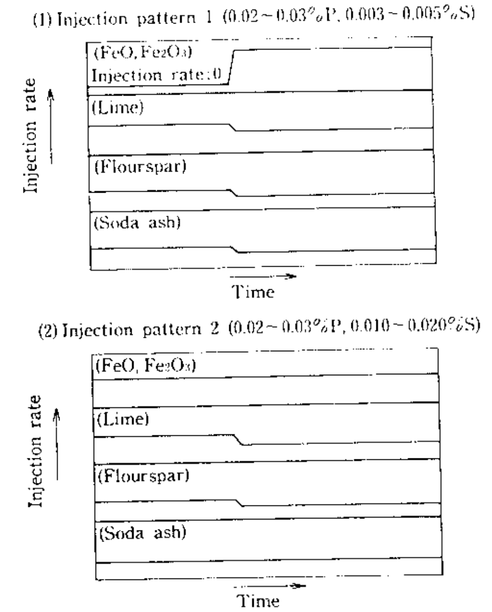


Fig. 9 Schematic explanation of injection patterns

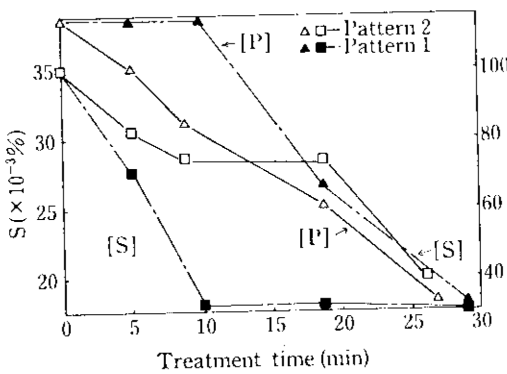


Fig. 10 Changes of the concentrations of P and S during the treatment

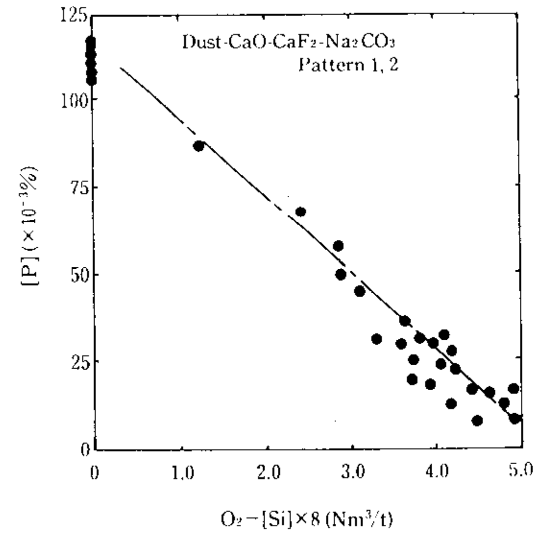


Fig. 11 Relation between [P] and oxygen consumption for dephosphorization[2)]

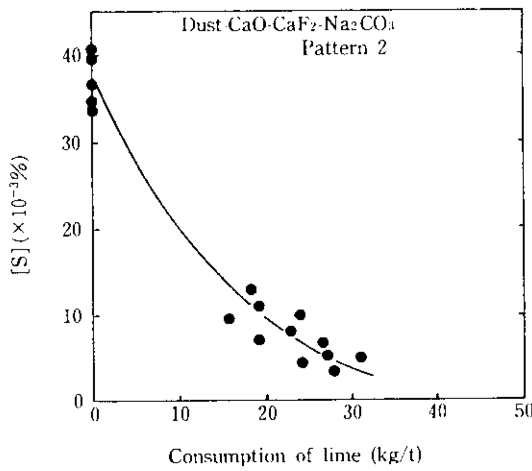


Fig. 12 Relation between [S] and consumption of lime[2)]

tern, hot metal with P ≤ 0.020% and S ≤ 0.005% can easily be obtained. Pattern 2 is adopted for steel grades not having strict sulfur content requirements. Dephosphorization and desulfurization proceed simultaneously in this pattern. Efficient dephosphorization and desulfurization can be carried out in both patterns because, with the online mixing method, the flux composition can be changed without interruption of the treatment.

The relationship between unit oxygen consumption excepting desiliconization (total unit oxygen consumption minus 0.08 × Si%), and phosphorus content after treatment is shown in **Fig. 11**. [2)] It is clear that the decrease in phosphorus content after treatment is virtually linear with increasing unit oxygen consumption excepting desiliconization and can be determined on the basis of this unit consumption alone. A phosphorus content of 0.020% can be obtained, for example, when the unit oxygen consumption is 4.0 $Nm^3/t$.

The relationship between unit burnt lime consumption and sulfur content is shown in **Fig. 12.**[2)] Sulfur content decreases with increasing unit burnt lime consumption and can be controlled on this basis. A sulfur content of 0.010% can be obtained when the unit burnt lime consumption is 21 kg/t.

In pattern 2, therefore, the unit oxygen consumption excepting desiliconization and the unit burnt lime consumption are calculated according to target phosphorus

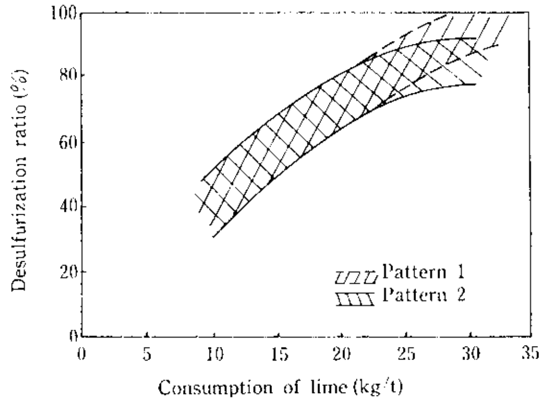


Fig. 13 Relation between desulfurization ratio and consumption of lime

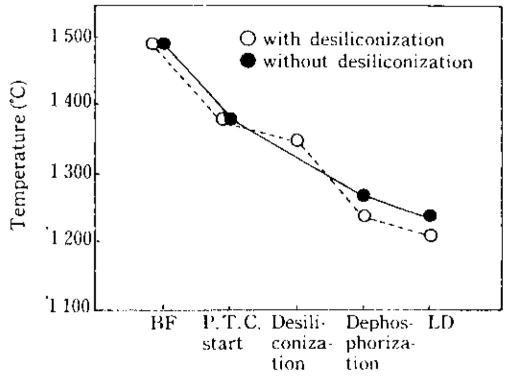


Fig. 14 Change of temperature of hot metal

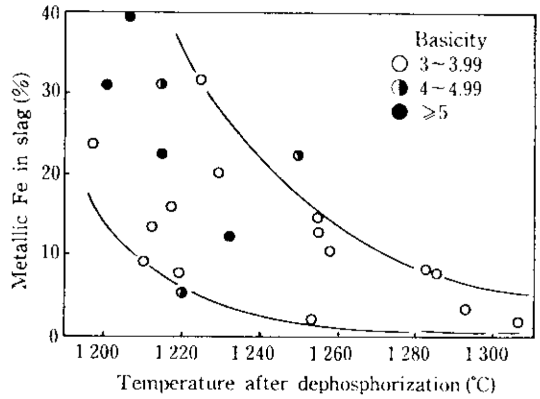


Fig. 15 Relation between metallic Fe in slag and temperature after dephosphorization

and sulfur contents and the flux composition is determined in view of these unit consumption values to ensure that dephosphorization and desulfurization proceed efficiently.

Effects of injection patterns on desulfurization efficiency during dephosphorization are shown in **Fig. 13**. The difference in desulfurization efficiency between the injection patterns is clearly observed in the low-sulfur region at unit burnt lime consumptions of 25 kg/t or more. Pattern 1, in which desulfurization is preferentially conducted in the initial stage of the treatment, is the more effective.

Pattern 1, which involves desulfurization, requires a treatment time about 10 minutes longer than pattern 2 and from this point of view, treatment efficiency is lower. However, because of its high desulfurization efficiency in the low-sulfur range, pattern 1 is adopted for target sulfur contents $S \leqq 0.005\%$, in consideration of treatment costs.

### 4.3 Hot Metal Temperature in Hot Metal Pretreatment

Changes in hot metal temperature from tapping from the blast furnace to charging into the converter are shown in **Fig. 14**. The hot metal temperature drops about 100 to 120°C after dephosphorization and decreases further by about 30°C when adjustment desiliconization is necessary.

The relationship between the hot metal temperature after dephosphorization and the content of metallic iron in the top slag is shown in **Fig. 15**. The metallic iron in top slag tends to increase abruptly when the hot metal temperature after treatment is 1 260°C or less. To prevent decreased yield, therefore, the target temperature after dephosphorization is 1 260°C or more.

### 4.4 TCC Operation and Torpedo Car Capacity

The operational process at the TCC is shown schematically in **Fig. 16**.[3] After the delivery of hot metal to the steelmaking plants, two torpedo cars are moved to the TCC and deslagging and cleaning are performed. In outline:

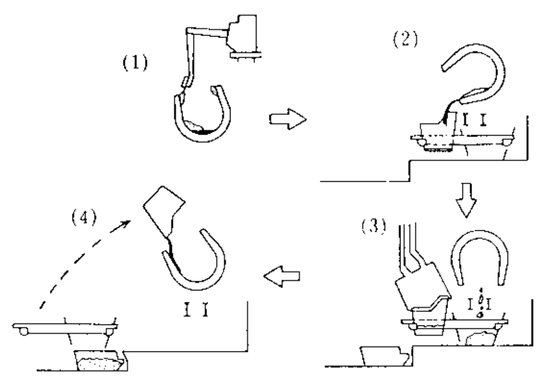


Fig. 16 Process flow of hot slag discharge[3] from torpedo car

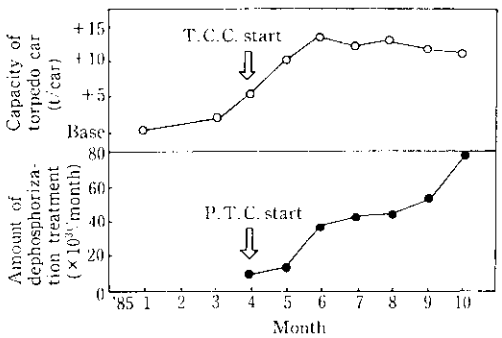


Fig. 17 Relation between amount of dephosphorization treatment and capacity of torpedo car

(1) Slag adhering to the hot-metal-receiving-opening of the torpedo car is removed by a slag breaker and a runner is formed so that the remaining hot metal can flow out.
(2) The hot metal remaining in the torpedo car is discharged into a hot metal ladle and is heated with burners.
(3) The slag remaining in the torpedo car is discharged into a slag scraper.
(4) A hot metal ladle is loaded onto a hot metal ladle transfer car provided with the slag scraper; this car is moved and the slag is pushed out into a slag pan. The hot metal in this ladle is then returned to the torpedo car while still in a molten state.

This operation involves discharging the hot metal remaining in the torpedo car, maintaining hot metal temperature by heating, and returning the hot metal to the torpedo car after deslagging. The method eliminates the problem of discharged skull and contributes to a decrease in the amount of skull generated.

The improvement in usable torpedo car capacity is shown in **Fig. 17**. Since the TCC began full scale operation, higher torpedo car capacity has been achieved, in spite of an increase in the total amount of fluxes injected into the torpedo car as increased amounts of hot metal are given pretreatment. This increase in torpedo car capacity results directly in a decrease in the hot metal temperature drop between tapping and delivery, and a decrease in unit consumption of torpedo car refractories. It is considered likely that these effects will gradually become more conspicuous in the future.

## 5 Refining of Pretreated Hot Metal[4]

Desiliconized hot metal and dephosphorized hot metal are supplied to the K-BOP converter, and dephosphorized hot metal to the LD-KGC converter. This contributes to cost reductions through a decrease in the unit consumption of converter fluxes (mainly burnt lime) and a reduction of added ferroalloys made possible by an increase in the manganese recovery rate.

The relationship between the phosphorus content of pretreated hot metal and unit burnt lime consumption is shown in **Fig. 18**. Unit burnt lime consumption decreases with decreasing phosphorus content of pretreated hot metal, and limeless blowing becomes possible when the phosphorus content decreases below a specified value.

An increase in the manganese recovery rate is expected due to a decrease in slag volume, resulting from a decrease in the unit consumption of fluxes, and an increase in blow-end carbon content. The relationship between blow-end carbon content and the manganese recovery rate is shown in **Fig. 19**. When a blow-end carbon content of 0.10% or more is maintained, both the K-BOP and the LD-KGC converter show high manganese recovery rates, 80% and 60% respectively.

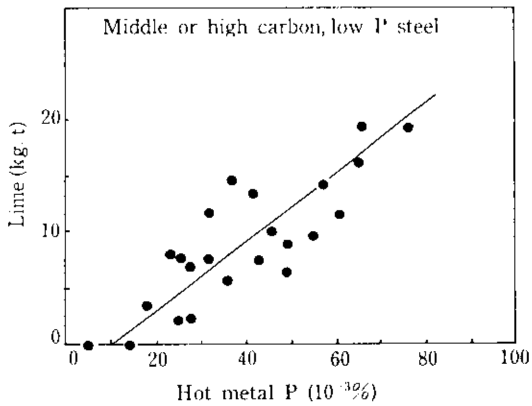


Fig. 18 Relation between lime and hot metal [P] in dephosphorized pig iron[4]

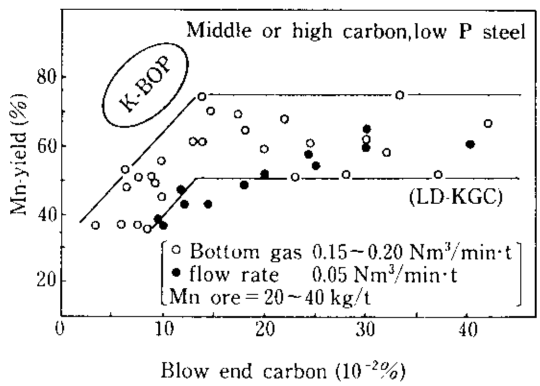


Fig. 19 Relation between Mn-yield and blow-end carbon at dephosphorized pig iron[4]

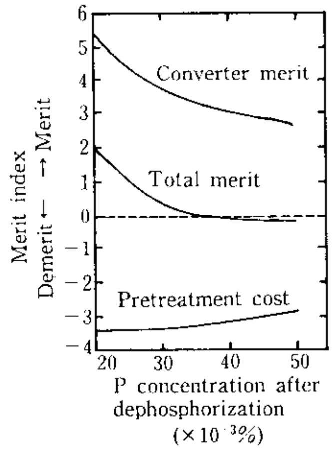


Fig. 20 Relation between P concentration and total merit

The relationship between the phosphorus content of pretreated hot metal and the total merit for refining is shown in **Fig. 20**. By lowering the phosphorus content of pretreated hot metal below a specified value, the maximum overall advantage can be obtained, namely, the reduced content of phosphorus in hot metal can decrease unit flux consumption and a volume of added felloalloys. Therefore, dephosphorization is conducted with the target phosphorus content after dephosphorization set at levels below this specified value.

For low-carbon steels, the manganese recovery rate is low and the advantage of reduced ferroalloy addition is smaller. In this case, therefore, desiliconized hot metal which can be pretreated at low cost is supplied to the converter, with satisfactory economic results.

## 6 Conclusions

The hot metal pretreatment facilities at the Mizushima Works comprise desiliconization equipment in the runner at the No. 4 BF, the Hot Metal Pretreatment Center for dephosphorization and desulfurization in the torpedo car, and the Torpedo Car Cleaning Center, facilities designed to prevent accumulation of slag in torpedo cars. These facilities came on stream in March 1985. The volume of hot metal treated by these facilities has gradually increased, and now stands at 220 000 t/month for desiliconization in the runner and 100 000 t/month for dephosphorization.

The facilities have the following features:

(1) Desiliconization equipment in the runner at the blast furnace:
- (a) The blasting method, which ensures high reaction efficiencies, was adopted for the addition of desiliconizing agents. The desiliconizing agents are added to the hot metal in the tilting spout exactly where the metal falls from the main runner.
- (b) To permit continuous desiliconization, two dispensers were installed, thus making rapid changeover possible.

(2) Hot Metal Pretreatment Center:
- (a) To shorten the time required by a series of treatments, the layout of the center is such that deslagging and the injection for dephosphorization can be conducted at the same location.
- (b) A mechanical slag dragger was installed.
- (c) An online mixing system that mixes four kinds of fluxes at the injection line was developed so that the flux injection rate can be controlled individually for each kind of flux.
- (d) A slanting lance was adopted to increase stirring capacity and reduce refractories costs.

With the online mixing system, flux composition can be changed without interrupting treatment at the Pretreatment Center, thus efficient dephosphorization and desulfurization can be carried out by matching flux injection patterns to target phosphorus and sulfur contents. The hot metal pretreatment facilities contribute to profitable operation by supplying desiliconized hot metal for the production of low-carbon steels and dephosphorized hot metal for medium- and high-carbon steels and low-phosphorus steels. Furthermore, it has become possible to achieve consistent mass production of very pure steels.


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