KAWASAKI STEEL TECHNICAL REPORT
No.24 (April 1991)

Total Hot Metal Pretreatment System at Kawasaki Steel

Masahito Suitoh, Kanji Aizawa, Masahiro Ariyosi, Ryoji Nagai, Hiroshi Nishikawa, Shigeru Omiya

Synopsis :
In order to further improve steel quality and to ensure stable operation, Kawasaki Steel Corporation completed facilities for the total hot metal pretreatment system both at Chiba and Mizushima Works in 1988. To realize the pretreatment of the whole quantity of hot metal, KSC used a torpedo car for its reaction vessel and adopted several unique techniques, like the post-mixing method of flux, a slanted injection lance, torpedo car cleaning system, torpedo car transportation system, etc. The total hot metal pretreatment has resulted in great improvement in product quality and stable refining operation. Typical examples are the high degree of cleanliness in ultra-low carbon steel, catch-carbon techniques for high carbon steel refining, stable refining of high Cr and stainless steel, minimizing the abnormal product, achieving long life of BOF, etc.

The body can be viewed from the next page.

Total Hot Metal Pretreatment System at Kawasaki Steel*


Masahito Suitoh
Staff Assistant Manager, Steelmaking Sec. II, Mizushima Works


Kanji Aizawa
Staff Assistant Manager, Development & Design Sec., Equipment Dept., Mizushima Works


Masahiro Ariyoshi
Staff Assistant Manager, Equipment Technology Sec., Mizushima Works


Ryoji Nagai
Plant Control Technology Sec., Mizushima Works


Hiroshi Nishikawa
Staff Deputy Manager, Steelmaking Technology Sec., Chiba Works


Shigeru Omiya
Staff Manager, Steelmaking Technology Sec., Mizushima Works

Synopsis:

In order to further improve steel quality and to ensure stable operation, Kawasaki Steel Corporation completed facilities for the total hot metal pretreatment system both at Chiba and Mizushima Works in 1988. To realize the pretreatment of the whole quantity of hot metal, KSC used a torpedo car for its reaction vessel and adopted several unique techniques, like the post-mixing method of flux, a slanted injection lance, torpedo car cleaning system, torpedo car transportation system, etc. The total hot metal pretreatment has resulted in great improvement in product quality and stable refining operation. Typical examples are the high degree of cleanliness in ultra-low carbon steel, catch-carbon techniques for high carbon steel refining, stable refining of high Cr and stainless steel, minimizing the abnormal product, achieving long life of BOF, etc.

1 Introduction

Prior to the oil crisis of 1973, technical development in the field of steelmaking centered on the quantitative expansion of crude steel output, together with the improvement of steel product quality. The large scale converters and continuous casting machines were introduced during this period. After 1973, however, demand for crude steel changed dramatically, and the main focus of technical development underwent a marked shift from quantity to qualitative improvement, energy savings, and resource conservation.[1] This trend is becoming increasingly strong, and the movement toward higher product quality requirements and greater diversity is proceeding at an accelerating pace.

In response to these changes, the steelmaking division of Kawasaki Steel introduced and developed the bottom blowing Q-BOP converter,[2] developed several combined blowing technologies such as the K-BOP and LD-KGC based on the conventional LD converter.[3,4] A variety of secondary refining techniques, such as RH degassing, were also introduced and further developed. The significance of these new techniques included not only improved stirring in the refining and purification processes for steel, but also the fact that the refining processes formerly concentrated on the converter could be distributed among appropriate reaction vessels. The division of functions was thus adopted as a means of achieving higher efficiency in refining reactions.

On the other hand, recent years have seen increasing emphasis on high purity, in addition to existing requirements for higher grade and higher value added products. In particular, demand is expanding for superclean steels to meet the sharply higher quality levels required in materials for cold rolling, and superpure, ultra-low P and S steels for specialty applications such as heavy plate and pipe. To meet these various needs, Kawasaki Steel undertook the development of hot metal pretreatment techniques which included desiliconization, dephosphorization, desulfurization,[5,6] and confirmed their advantages for product quality.[7,8] Using these processes, comprehensive systems capable of treating the entire output of hot metal established at both Chiba Works and Mizushima Works in 1988.[9-12]

The aim of the hot metal pretreatment is to differentiate the refining functions of the converter and restrict

* Originally published in *Kawasaki Steel Giho*, 22(1990)3, pp. 143–149

the converter to two functions, decarburization and heating of the melt, completely eliminating its role as a dephosphorizing vessel. By simplifying and standardizing the converter refining process, it has been possible to achieve a significantly higher total process capability, meaning distinctly higher steel quality, a reduction in product quality variations even at higher quality levels, higher quantitative accuracy in as-tapped steel output, and better reliability in meeting operating schedules, thus ensuring more stable converter operation.

This report discusses the philosophy and aims of the total hot metal pretreatment system, describes the high-volume, high-efficiency hot metal pretreatment processes developed by Kawasaki Steel for the system, and provides examples of the technical improvements achieved in the steel refining process.

2 Aims of Establishment of Total Hot Metal Pretreatment

The introduction of the Q-BOP converter in 1977 gave great impetus to the development of hot metal pretreatment at Kawasaki Steel. Following a period of technical development, a commercial-scale hot metal pretreatment equipment was put into service at Chiba Works in 1984 and at Mizushima in 1985.[13-19] In terms of pig iron output, the capacity of the original equipment was 20–50% of the total hot metal output. However, with further experience in refining and operation with pretreated hot metal, a decision was made to extend pretreatment to the entire hot metal output. Construction work for upgrading pretreatment capacity at both Works was finished by the end of 1988, thus establishing the total hot metal pretreatment system.[9-12]

The aim of this program, as mentioned previously, was to achieve a marked improvement in steel product quality, production stability, and process capabilities (improved accuracy in meeting quality, quantity, and on-schedule processing), while at the same time realizing a reduction in refining costs. The key to achieving these aims was the simplification and standardization of converter operations by restricting the converter to the two functions of hot metal decarburization and heating. To do this and reduce the converter refinig burden, which is a major factor in steel quality, it was necessary to eliminate the dephosphorizing load on the converter by adopting hot metal pretreatment.

The most important cause of poor steel cleanliness is oxygen in the converter slag. On the other hand, highly oxygenated slag is essential to dephosphorization in the converter. Thus dephosphorization stands in a reciprocal relationship to cleanliness, which is adversely affected by high oxygen content, and removing the dephosphorizing burden from the converter therefore makes possible a remarkable reduction in the negative effects of converter slag.

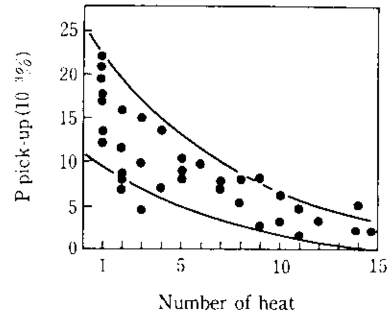

Fig. 1 Change in P pick-up from furnace since the application of pretreated hot metal in place of conventional hot metal

Other problems arise when high and low phosphorus blowing are practiced successively in the same vessel. After high phosphorus blowing, a large quantity of phosphorus will remain in the vessel as a result of slag adhering to the converter walls, even if all free slag is removed. If the same vessel is next used to blow dephosphorized hot metal, the contaminated lining will cause phosphorous pick-up by the melt. The fact that the amount of phosophorous contamination varies widely and is unpredictable makes stable operation of the converter all the more difficult under these conditions. **Figure 1** illustrates this problem. When pretreated hot metal is blown after blowing with high P hot metal, phosphorous pick-up from the furnace lining does not decrease to a negligible level until about the tenth heat, at which point the vessel can be considered clean.[20] From this, it can be understood that the dephosphorizing burden cannot be effectively eliminated unless total pretreatment is adopted.

The following is a summary of the main results expected from the adoption of total hot metal pretreatment:

(1) Improvement of Steel Quality
- (a) Reduction of (T.Fe) in converter slag and prevention of excessive oxidation of the melt
- (b) Improvement in the quality of ladle slag as a result of reduced P in the converter slag
- (c) Improved steel cleanliness as a result of (a) and (b)
- (d) Reduction in and stabilization of tapping temperatures with use of the catch-carbon method and recovery techniques for in-furnace Mn and Cr
- (e) Establishment of a reliable mass-production technique for refinig ultra-low P steels

(2) Shorter and Stable Lead Times
- (a) Improvement of the blowing control system as a result of simplification and standardization of the converter blowing operation
- (b) Enhancement of converter process capabilities, including improved accuracy of chemistry con-

trol, improved hit accuracy of target tapping weight due to more consistent yield rates, and improved accuracy in maintaining operating schedules as a result (a) above
   (c) Shorter lead times and reductions in excess semifinal products by minimizing off-standard production
(3) Reduction in Refining Costs
   (a) Reduction in converter refractory costs (as a result of (1)-(a), (1)-(d), and (2)-(a))
   (b) Reduction in the consumption of slag-making submaterials
   (c) Increased steel yield due to the decreased volume of slag in the converter
   (d) Reduction in consumption of FeMn alloys (as a result of (1)-(d))
   (e) Recirculation of converter slag as a sintering material as a result of reduced slag P content

3 Overview and Special Features of Hot Metal Pretreatment Process

In order to reduce the functional burden on the converter and realize the improvements in refining functions discussed above, stable pretreatment of hot metal in mass quantities is necessary. Temperature and composition targets must be met, especially for P and S, and the required volume of hot metal must then be delivered to the converter shops according to schedule. When the torpedo cars conventionally used to transport hot metal from the blast furnaces to the steelmaking shops are also used as pretreatment vessels, various problems arise, including the complexity of torpedo car transport control, reductions in torpedo car capacity due to slag adhesion to torpedo inner wall, and contamination of the hot metal by residual P and S in the torpedo. The following techniques were adopted in the Kawasaki Steel hot metal pretreatment process to solve these problems and make possible the pretreatment of the total hot metal output. (The following discussion describes practices at Mizushima Works by way of example.)

3.1 Layout and Outline of Process

Figure 2 shows the overall layout of hot metal pretreatment equipment and related facilities; **Figure 3** presents a general outline of the process. Cast-house desiliconization equipment is provided at all operational blast furnaces, making it possible to desiliconize the entire pig iron output. The dephosphorization and desulfurization facilities (hot metal pretreatment equipment) are located at an intermediate position between the blast furnaces and steelmaking shops to allow for smooth operation of transporting torpedo cars. Each steelmaking shop also operates a Torpedo Cleaning Center (TCC) for the removal of slag adhering to the torpedos after use.

3.2 Cast-house Desiliconizing Equipment

A schematic view of the cast-house desiliconizing equipment is shown in **Fig. 4**. The features of the main items of equipment are discussed below.
(1) A high-efficiency desiliconizing reaction is obtained by the use of flux blasting to introduce the desiliconizing agent into the pig iron in the BF runner. A two-step blasting method is used to prevent slag formation in the torpedo while at the same time

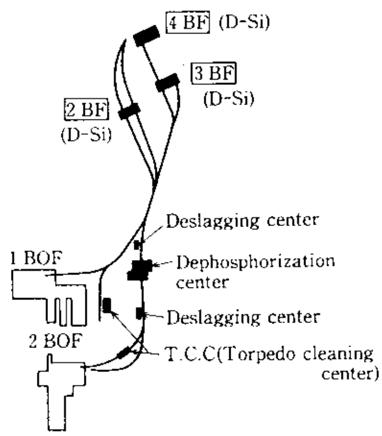

Fig. 2 Layout of hot metal pretreatment process at Mizushima Works

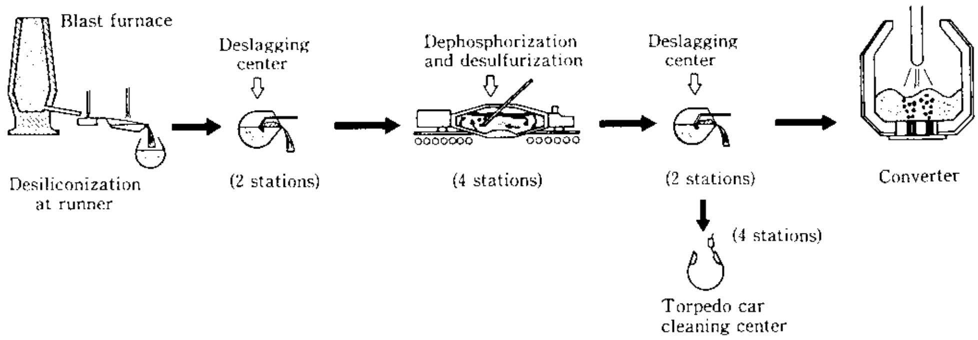

Fig. 3 Hot metal pretreatment process at Mizushima Works

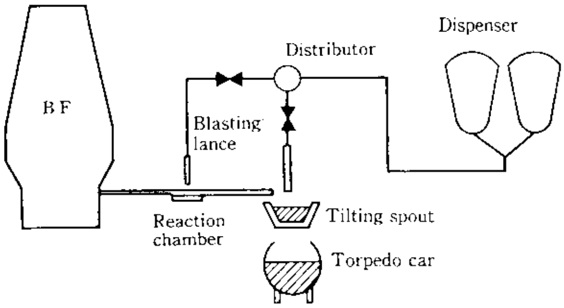

Fig. 4 Schematic view of desiliconization facilities

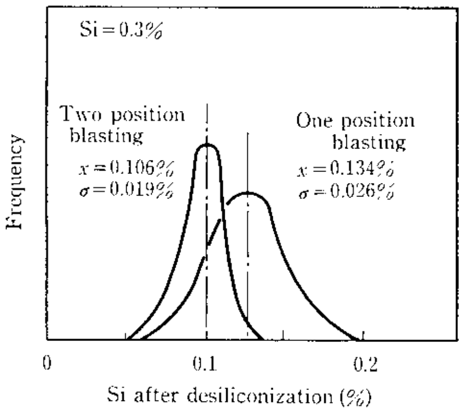

Fig. 5 Si content after desiliconization at blast furnace

achieving high-volume desiliconization.[21] First step blasting is conducted at the reaction chamber of the main runner, while the second step is at the point where the hot metal flowing from the runner drops from the tilting spout. This latter practice is particularly effective for desiliconizing, since it takes advantage of the natural kinetic energy of the falling metal. As shown in **Fig. 5**, stable desiliconization at the 0.11% Si level and high oxygen efficiency for desiliconizing (65–70%) have been obtained.

(2) Two types of desiliconizing agent used; dust from the sinter plant dust collector, which serves as an oxygen source, and $CaCo_3$, which is used to adjust slag basicity.
(3) To make possible the desiliconization of all hot metal, each dispenser is comprised of two units. Instant change-over of the dispensers permits uninterrupted operation of the desiliconizing process.
(4) The measuring and mixing of desiliconizing agents and the blasting process are fully automated using DDCs.

3.3 Hot Metal Pretreatment Equipment

In the hot metal pretreatment process, the torpedos are used as reaction vessels. To achieve stable hot metal

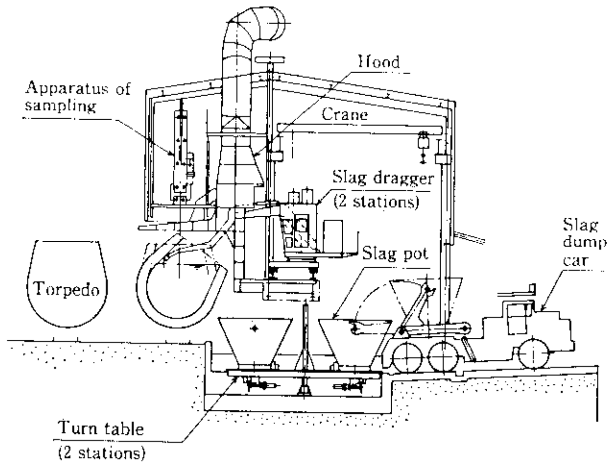

Fig. 6 Vertical sectional view of deslagging equipment

transportation simultaneously with a high efficiency hot metal pretreatment operation, the system is provided with the following features:

(1) Deslagging equipment is located at two positions, between the desiliconizing process at the blast furnaces and the hot metal pretreatment center, and between the hot metal pretreatment center and the steelmaking shops. Each of these two deslagging centers is capable of handling two torpedo cars simultaneously. The mechanical deslagging equipment (**Fig. 6**) is designed to cope with any foreseeable changes in slag properties. Using this equipment, both desiliconized slag and de-P and de-S slag are efficiently removed, reducing the amount of slag adhering to the interior of the torpedo and ensuring more stable de-P and de-S performance.
(2) With the hot metal pretreatment equipment (de-P and de-S), it is possible to handle four torpedo cars simultaneously. The monthly treatment capacity of the system is 600 000 t. The physical construction of the facility is shown in a sectional view in **Fig. 7**. A summary of the main equipment is given in **Table 1**. The main divisions of hardware are the sintered ore grinding mill, the powder handling equipment, the lance set-up, and the dust collection facilities. The entire system, as shown in **Fig. 8**, is automated under the control of DDCs. Further, monitoring and control functions of four torpedo cars are centralized at a control panel enabling a single operator to perform powder injection at all stations.
(3) In order to obtain flux of a composition which will meet de-P and de-S standards, a post-mix method was developed. This method permits mixing of four types of powder according to process requirements and is incorporated in the injection line,[22] eliminating the need for separate flux blending equipment

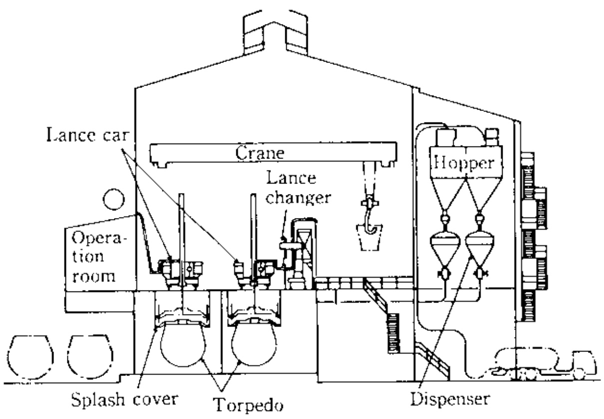

Fig. 7 Vertical sectional view of hot metal pretreatment equipment

Table 1 Specifications of hot metal pretreatment equipments

Item	Specification
Flux	
Dephosphorization	Sintered ore, lime, flour spar
Desulfurization	Soda ash
Injection equipment	
Dispenser	4 dispensers × 4 lines
Method of flux mixing	On line mixing
Injection rate	Max. 600 kg/min
Lance car	Double lances × 4 lines
Dust catcher	
Exhaust gas cooler	Open channel air cooler
Capacity	50×10^4 m³/h × 2 lines (at 120°C)
Slag dragger	Mechanical dragger × 2 lines × 2 stations
Sintered ore grinding mill	
Type	Vertical roller mill
Capacity	30 t/h

and making possible the continuous control of flux composition to optimum values during treatment. The introduction of this feature has resulted in a major reduction in flux costs and improved composition hit accuracy.

(4) Lances are of lightweight slanted type, with an inner diameter of 32 mmϕ. The design allows high speed blowing of pretreatment agents into the torpedo and produces a good hot metal flow with no reaction dead zone in the vessel, resulting in consistent, high efficiency hot metal pretreatment. In addition, two lances are available at each station, and the introduction of robots for the lance exchange has contributed greatly to the establishment of an automated, high-speed operation.

(5) A computer-aided operational control system for hot metal pretreatment was introduced to achieve automated high-efficiency flux injection. In this system, target compositions for P and S are determined by the chemical composition and the amount of hot metal, in-torpedo free board, residual slag thickness, and information on the heat to be made from the hot metal. According to the P and S determined, the amount of each flux to be used for de-P and de-S and its injection pattern are set up for practice. The composition hit accuracy obtained after hot metal pretreatment using this system in combination with the previously mentioned torpedo cleaning facilities is ±0.003% for P and ±0.002% for S, making it possible to supply hot metal of the optimum chemical composition to the steelmaking shops.[8]

3.4 Torpedo Car Cleaning Equipment

Removal of slag from the interior of the torpedo and the normal maintenance of torpedos in "clean" condition is intended not only to prevent slag slopping during hot metal pretreatment, but is also essential to the improvement of process efficiency, the improvement of chemical composition hit accuracy after pretreatment, and the securing of a predictable torpedo car inner capacity. As shown in Fig. 2, the Mizushima Works hot

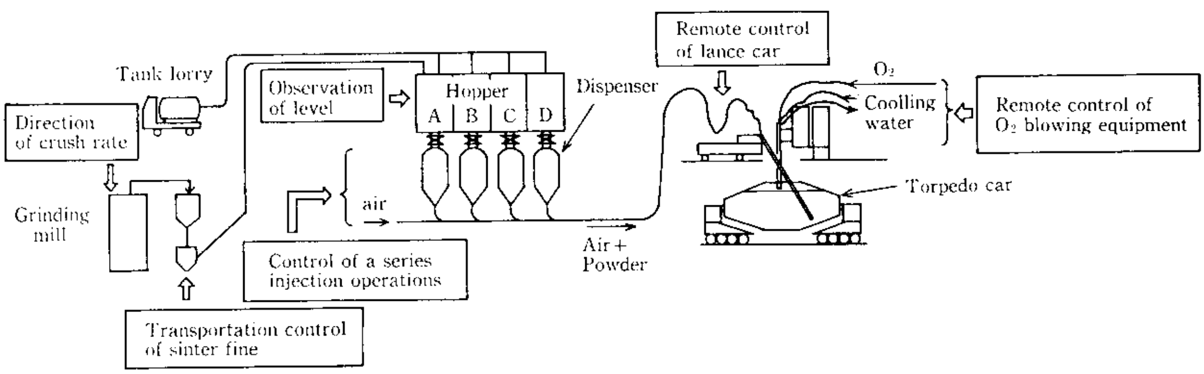

Fig. 8 Outline of control system at hot metal pretreatment center

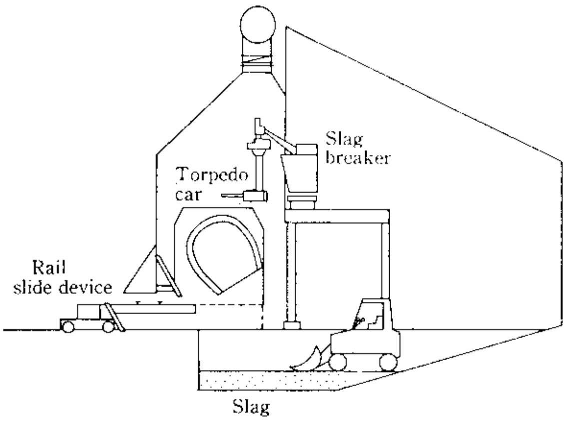

Fig. 9 Schematic view of Torpedo Cleaning Center (TCC)

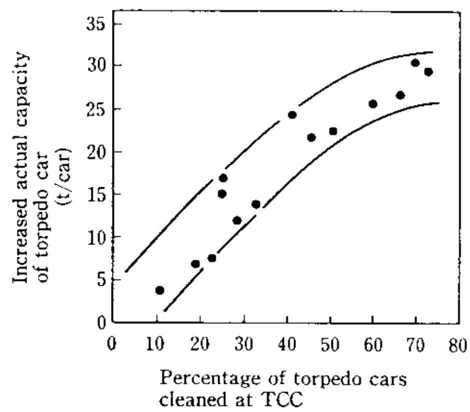

Fig. 10 Influence of torpedo cleaning on actual capacity of torpedo car

metal pretreatment system is provided with high-efficiency mechanical deslaggers both before and after the pretreatment center. This equipment is used to clear slag from the interior of the torpedos. Each steelmaking shop is equipped with a torpedo car cleaning facility of the type shown in **Fig. 9**. Immediately after the hot metal is discharged from the torpedo, a slag breaker is used to remove solidified slag and skull from the mouth of the vessel. The tropedo is then inverted 360° and a rail slide device is used to remove any residual slag from the interior of the car.[23,24] The effect of torpedo cleaning on the usable capacity of torpedo cars is shown in **Fig. 10**. Although the following point will be discussed below, torpedo cleaning also plays an important role in the reduction of P pick-up when hot metal is charged into the torpedo. For these reasons, cleaning of the interior of torpedo cars is essential to stable hot metal pretreatment in a mass-scale pretreatment operation.

3.5 Control System for Torpedo Cars

At Mizushima Works, approximately 40 torpedo cars with a capacity of 250 t each are used to transport hot metal from the blast furnaces to the steelmaking shops. Since the pretreatment function was added to the hot metal transport route, the establishment of this high-volume hot metal pretreatment system resulted in increased transit time between the blast furnaces and steelmaking shops and greater complexity of the torpedo travel routes than was the case with the conventional system. In addition, it was necessary to reduce actual hot metal weight of the torpedos to approximately 200 t in order to secure the additional freeboard needed to prevent slag slopping during treatment. Generally, such changes would require an increase in the number of torpedo cars. To avoid this and establish a full-scale pretreatment system without increasing the existing number of torpedo cars, it was necessary to develop a transportation diagram system.[8]

The system is composed of a on-line computer (O/C), a process computer (P/C), and the various units of equipment linked to the process computer for automatic operations. Torpedo car travel schedules and insructions related to the pretreatment operation are processed by these computers. The three main functions of the torpedo car control system are as follows:

(1) The system tracks the torpedo cars and diesel locomotives, and monitors their current location and progress by means of car number reading devices, making it possible for one operator to maintain appropriate control of torpedo car movement in accordance with hot metal pretreatment schedule information.
(2) Schedules for cast-house desiliconization and hot metal pretreatment are prepared in synchronization with converter shop steelmaking schedules and communicated to the O/Cs and P/Cs.
(3) All torpedo cars are equipped with a braking system which operates automatically when the topedo is uncoupled from the locomotive. Faster response has thus been achieved in car allocation. In particular, waiting time under the blast furnace cast-house floor has been markedly reduced.

These functions ensure efficient movement of torpedo cars, making it possible to handle the entire hot metal output of the works with existing rolling stock. Travel time has been reduced and the turnover rate improved, and even at the current hot metal pretreatment ratio of 70–80%, a torpedo turnover rate of more than 3.0 turns a day is being maintained.

4 Operational Results Following Improvement of Hot Metal Pretreatment System

Construction work for the enhancement of the hot metal pretreatment equipment at Mizushima Works

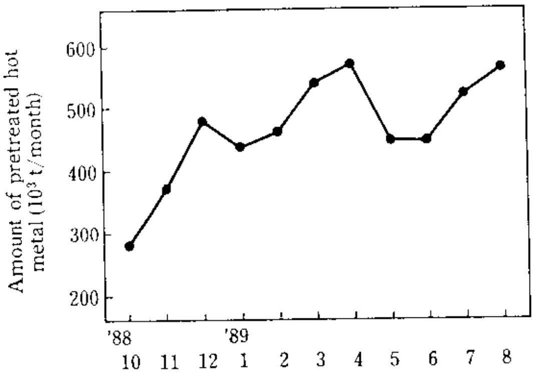

Fig. 11 Change in amount of pretreated hot metal

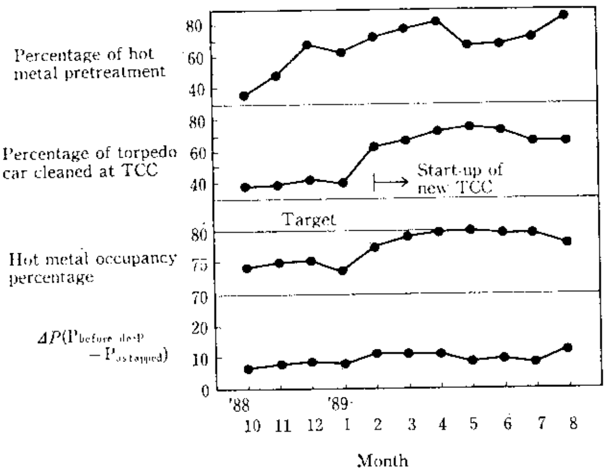

Fig. 12 Change of torpedo car conditions

Table 2 Change in contents of [Si], [P] and [S] of hot metal and flux consumptions

	As tapped	Before de-P, de-S	After de-P, de-S
Si (%)	0.30	0.10±0.05	tr
P (%)	0.115	0.125	0.010~0.030
S (%)	0.025	0.025	0.002~0.020
Flux consumptions (kg/t)	· Sinter dust 21 · $CaCO_3$ 1.4		· Sintered ore 30 · Lime 10 · Flour spar 0.4 · Soda ash 0.5~9

was completed in October 1988, and a smooth rating up was achieved.[9] Changes in the amount of hot metal pretreated before and during the rating up period are shown in **Fig. 11**. The hot metal ratio varies with changes in hot metal tapping capacity, affecting the amount of hot metal which is pretreated, but recently, the hot metal pretreatment ratio has been in the range of 70–80%. As can be seen from **Fig. 12**, in spite of the large increase in the hot metal pretreatment ratio following the upgrading of torpedo cleaning capacity, good performance has been maintained in terms of both hot metal occupancy (as a percentage of the official capacity of the torpedo) and P pick-up from the torpedo. **Table 2** shows changes in the chemical composition of hot metal during hot metal pretreatment and the unit consumption of the various fluxes.

5 Advantages of Hot Metal Pretreatment in Refining Process

One condition for realizing the full benefit of hot metal pretreatment is the use of a strongly stirred top-and-bottom blowing converter as the primary refining vessel, since powerful agitation of the bath results in an improved decarburization ratio and a reduction in the (T.Fe) of the slag. This in turn facilitates the prevention of excessive oxidation of the molten steel, which is essential for the production of clean steels. Blowing at low (T.Fe) levels and with only small amounts of slag has also resulted in improved yields of steel and Mn, and has made it possible to take fuller advantage of Mn reduction in the converter by the direct addition of Mn ore. In addition, these changes have greatly reduced the rate at which converter refractory material is lost to the molten bath, resulting in extended furnace life and better operational stability.

The converters used at Chiba Works are Q-BOP and K'BOP vessels, while those at Mizushima are of the K-BOP and LD-KGC type. All these converters are either bottom blowing or combined blowing furnaces, and as such are characterized by strong stirring. Thus, the company's equipment set-up is ideally suited to fully realize the advantages of hot metal pretreatment. The operational results obtained in refining are discussed below.

5.1 Techniques for Improvement of Molten Steel Cleanliness

In the production of ultra-deep drawing cold rolled steel sheet, the key points for obtaining superior product quality are first to reduce inclusions to the absolute minimum, and then to completely prevent oxygen contamination during casting. Because the largest source of oxygen contamination is ladle slag, it is essential to limit the oxygen source in the ladle slag during casting, which means maintaining the lowest possible (T.Fe) level. The company therefore developed high basicity blowing techniques for the Q-BOP and K-BOP using pretreated hot metal, and has thereby reduced slag (T.Fe) at blow end. Allowing the slag to solidify in the converter has also reduced the amount of slag carryover into the ladle. The addition of an Al-base flux to the

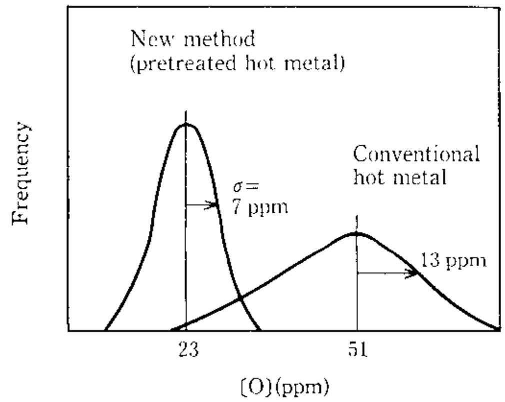

Fig. 13 Improvement of cleanness of steel by new refining method

ladle slag has improved slag quality, and slag (T.Fe) figures of under 4% are now being consistently maintained. As shown in **Fig. 13**, a marked reduction in the oxygen concentration of the bath has been obtained.[25] A 80% reduction in the former rate of cold rolled material defects has been achieved through the adoption of clean steelmaking techniques using pretreated hot metal.

5.2 Reduction in Abnormal Heats

Abnormal products, that is, semifinal products with specifications not matching those of the production plan, consist mainly of materials with non-standard chemistries and materials which produce unsatisfactory results in the casting process and surplus slabs. Such materials are, when possible, reassigned to other orders, but additional material must then be produced for the original order.

To improve delivery performance, the volume of semifinal products not rolled for original orders should be reduced. **Figure 14** shows the trend in the ratio of abnormal semifinal products requiring order reassignment during the start-up period of the second stage pretreatment facilities. As the figure shows, the ratio of abnormal semifinal products has decreased with expanded use of pretreated hot metal due to a marked improvement in the consistency of converter performance and the stablization of continuous casting operations achieved as a result of better steel cleanliness. At the same time, stabilized steel yield has also reduced the volume of excess semifinal products.

5.3 Catch-Carbon Blowing Techniques for High Carbon Steels

Prior to the introduction of the new system, when high carbon steels were produced using ordinary hot metal, the unreliability of dephosphorization performance made it difficult to control C at blow-end, and it was not possible to make appropriate use of the catch-carbon technique. Under these conditions, changes in the tapping plan were frequently required by drops in C content caused by sharply increased tapping temperatures and slag overoxygenation. In contrast, with continuous use of pretreated hot metal, the catch carbon method can be employed with consistent results, as shown in **Fig. 15**, since there is no de-P load on the converter and blowing can be conducted in a clean furnace. Refining has thus been stabilized, and tapping temperatures have been sharply reduced.

5.4 Refining Techniques for High-Mn, High-Cr, and Stainless Steels

As mentioned previously, removing the dephosphorizing burden from the converter permits ultra-low in-furnace slag operation and lowering of slag oxidation levels. These changes have made it possible to take greater advantage of Mn recovery by the addition on Mn ore to the converter. High volume Mn ore operation has resulted in a broad reduction in the consump-

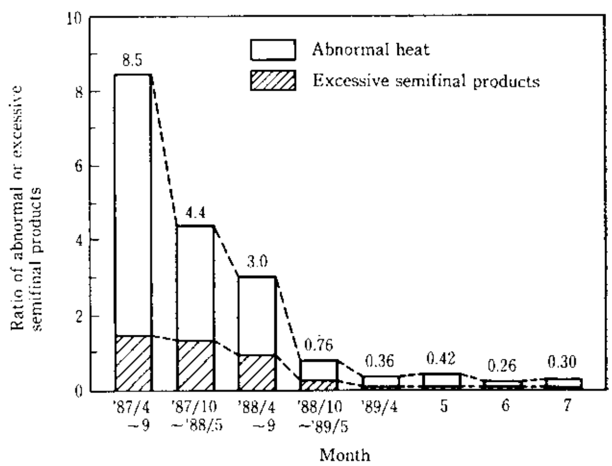

Fig. 14 Change in percentage of abnormal or excessive semifinal products

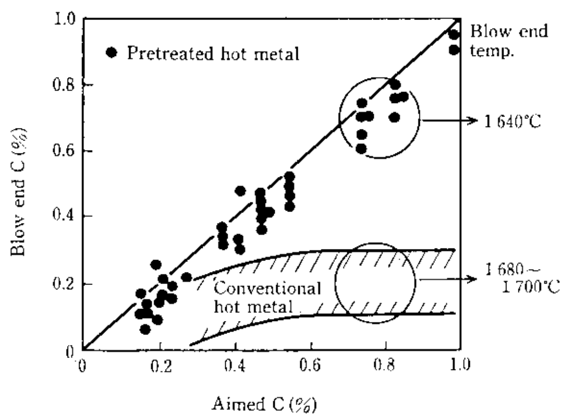

Fig. 15 Relationship between aimed C and blow end C

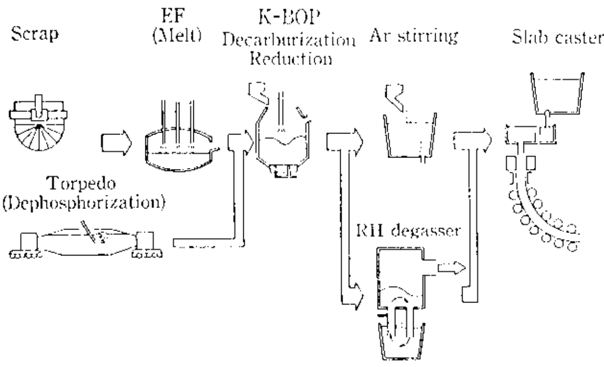

Fig. 16 Flow chart of making stainless steel by K-BOP

tion of FeMn alloys.[26]

The top-and-bottom blowing LD-KDG furnaces at Mizushima Works use a dilute-gas blowing technique in which top blown oxygen is mixed with inert gas to reduce the partial pressure of CO at the end of decarburization in high Cr steel refining, making it possible to continue decarburization into the low carbon region while maintaining a high Cr yield.[27] Using this blowing technique in combination with hot metal pretreatment, a fast, reliable method of producing high alloy steels such as 5-13% Cr and 13% Mn has been established.

At Chiba Works, a mass production process for stainless steel has been established using the K-BOP converters and an melting furnace (MF—electric arc furnace) in combination (**Fig. 16**). Total hot metal pretreatment is a necessary condition for this process, since it allows a marked reduction in the charging requirements of the MF, substantially reducing operation time and improving productivity.

5.5 Service Life of Converter Refractories

The lowering of (T.Fe) is brought about by the use of pretreated hot metal in converter refining and the lowering of tapping temperatures which has been made possible by use of the catch-carbon method and Mn recovery technique have substantially reduced the converter refractory wear. Further, reductions in the volume of slag in the converter have allowed a reduction in the specific inner volume of furnace. The adoption of long bricks in the LD-KGCs at Mizushima Works has been particularly advantageous, resulting in the establishment of a world furnace-life record of 8119 heats.

6 Conclusions

Kawasaki Steel's Chiba and Mizushima Works have established hot metal pretreatment systems capable of handling the entire hot metal output of each site. The improvement in product quality, rationalization, and enhanced process capabilities achieved in steelmaking refining with the adoption of this system have greatly exceeded expectations, resulting in a revolutionary improvement in the steelmaking process.

The fundamental factor in achieving this improvement was elimination of the dephosphorizing burden on the converter, which resulted not only in stabilized production of high purity steel, but also a sharp upgrading of steel cleanliness and of quantitative and timewise accuracy in the refining process, all of which have contributed greatly to the establishment of a reliable production system and the stabilization of delivery schedules. In economic terms, on the other hand, the development of a rationalized, high-efficiency comprehensive hot metal pretreatment process, in spite of the complexities involved, has resulted in higher steel yield, lower unit costs for Mn recovery and various types of secondary materials, and improvement in the service life of converter refractories, and has thus brought about a striking reduction in steelmaking costs.

References

1) Nishiyama-kinen Gijyutsukohza (Proceeding of Nishiyama Memorial Lecture), No. 100, 101 (1984)
2) M. Saigusa, J. Nagai, F. Sudo, H. Bada, and S. Yamada: *Ironmaking and Steelmaking*, 7(1980)5, 242
3) J. Nagai, T. Yamamoto, H. Take, I. Ohishi, H. Ohmori, and Y. Iida: *Kawasaki Steel Giho*, **15**(1983)2, 106
4) R. Tachibana, N. Takashiba, M. Kuwayama, A. Yamane, M. Maeda, and H. Osanai: *Kawasaki Steel Giho*, **17**(1985)4, 357
5) T. Nozaki: Private Communication
6) O. Haida, H. Takeuchi, T. Nozaki, T. Emi, and F. Sudo: *Tetsu-to-Hagané*, **68**(1982)13, 1744
7) H. Kondo, H. Bada, H. Yamada, K. Hamagami, and H. Ohtani: *Tetsu-to-Hagané*, **71**(1985), S985
8) M. Suitoh, S. Omiya, S. Hiwasa, N. Kitagawa, A. Ueda, and H. Take: *Kawasaki Steel Giho*, **19**(1987)4, 222
9) F. Sudo, T. Yamamoto, M. Suitoh, M. Ariyoshi K. Aizawa, and R. Nagai: *CAMP-ISIJ*, **2**(1989), 104
10) F. Sudo, T. Yamamoto, M. Suito, R, Nagai, H. Yamane, and K. Akimoto: *CAMP-ISIJ*, **2**(1989), 105
11) R. Asaho, S. Yamada, N. Yasukawa, T. Suzuki, H. Nishikawa, and S. Tomiyama: *CAMP-ISIJ*, **2**(1989), 214
12) H. Nishikawa, H. Kondoh, M. Aratani, R. Asaho, and S. Yamada: *CAMP-ISIJ*, **2**(1989), 215
13) M. Washio, S. Yamada, H. Yamada, K. Emoto, S. Hamada, and A. Mori: *Tetsu-to-Hagané*, **71**(1985), S109
14) M. Washio, K. Hamagami, H. Bada, M. Ohtani, and H. Yamada: *Tetsu-to-Hagané*, **71**(1985), S946
15) M. Yokoi, H. Take, H. Ohzu, M. Yoshida, T. Asano, and T. Imai: *Tetsu-to-Hagané*, **71**(1985), S951
16) M. Suitoh, S. Hiwasa, H. Take, T. Imai, T. Kometani, and M. Yoshida: *Tetsu-to-Hagané*, **72**(1986), S213