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Technical Report

Development of Mechanization and Labor Saving Technology for Refractory Maintenance

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Abstract

Development of mechanization and labor saving technology for refractory maintenance was outlined in Oita Works, Nippon Steel Corp. Brik lining was mainly used and needed the skilled worker. The improvement of work efficiency have been required. In the standpoint of mechanization and labor saving technology, the monolithic lining and has been applied and the centralization of maintenance shops, which improved the refractory cost and labor saving.

1. Introduction

Refractory maintenance work performed in the iron and steel industry requires special skills, which take many years to acquire, and involves heavy muscular labor under extremely harsh conditions—being hot, dusty and noisy. Because of all this, many refractory maintenance workers do not remain long in service at their workplaces. That was such a serious yet common problem at most steelworks throughout the country that it was considered an urgent necessity to make improvements. At Nippon Steel's Oita Works, in particular, the refractory maintenance shops were distributed across several sites and hence, the utilization efficiency of the maintenance workers and equipment was not very high and measures necessary to improve the working environment were difficult to implement. Under such conditions, we integrated the maintenance shops (Step I) with the aim of significantly enhancing the efficiency of manpower and equipment utilization, and pressed ahead with the development of mechanization and labor saving technology (Step II) to significantly improve maintenance work. This paper describes the developments we made and the results of our efforts to reduce labor and cut refractory costs.

2. Problems Related to Refractory Maintenance and Concepts for Improvements

2.1 Former maintenance practices and inherent problems

At the Oita Works, the refractory maintenance shops were split between five different sites within the steelmaking plant (**Fig. 1**). Therefore, the maintenance work was afflicted by a number of problems, such as: 1) poor manpower efficiency due to a surplus of main-

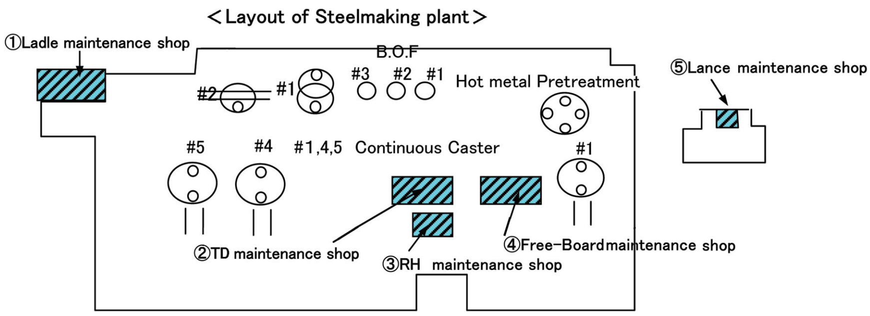

Fig. 1 Outline of refractory repair shops in steel making plant at Oita Works

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tenance staff, 2) low equipment activity rate due to the presence of redundant sets of similar maintenance equipment, and 3) a considerable waste of time and reduced operational efficiency due to the inefficient way of operating the cranes that handle materials within the plant.

A work analysis we conducted showed that incidental operations, such as material handling, drying, making arrangements and rearrangements, accounted for 37% of all maintenance work. Thus, improving the efficiency of those incidental operations, too, was a major issue. In order to resolve this and other problems, it was necessary to integrate the distributed maintenance shops and review the inefficient manner in which bricklaying was performed. Therefore, we discussed and implemented these improvements as Step I.[1)]

2.2 Concept for improving refractory maintenance

In order to resolve the problems mentioned above, we discussed making the following improvements:

1) Reorganizing the equipment-based maintenance work into one based on elementary work units
2) Centralizing the sources of dust so that the work environment can be improved efficiently
3) Replacing the inefficient bricklaying method with highly efficient monolithic refractory lining.

3. Integration of the Maintenance Shops and Improvement of the Work Environment (Step I-1)

In integrating the maintenance workshops, we rearranged the equipment according to elementary work units: (1) stripping of refractories, (2) reconditioning of hardware, (3) re-lining/repair, and (4) other work. At the same time, the maintenance area was divided into two sections—one section for ladles, RH vessels and other large equipment, and the other for RH snorkels, lances and other small parts. All this was to enhance the efficiency of manpower utilization and enable maintenance equipment and devices to be shared by all maintenance personnel. In addition, in order to improve the efficiency of monolithic refractory lining work, a transfer car mounted with a mixer was introduced and the furnace equipment storage facilities were integrated into one within the working area. An outline of the integrated maintenance shop is presented in **Fig. 2**.

At the same time as the integration of the maintenance shops, we implemented measures to improve the maintenance work environment. For example, a dust-collecting hood enclosing the refractory stripping ground—the major source of dust—was installed. In addition, in sections that are dedicated to the maintenance of hardware and the mixing of refractory materials, local exhaust systems were installed.

4. Promotion of Development to Expand Application Scope for Monolithic Refractories (Step I-2)

4.1 Concept for expansion of application scope for monolithic refractory

From the standpoint of coping with the shortage of skilled bricklayers, enhancing the efficiency of refractory lining workers, prolonging the life of equipment, cutting the cost of refractories, etc., we pressed ahead with improvements and developments to shift from conventional bricklaying to monolithic refractory lining.

The following advantages of monolithic refractory lining can be cited:

1) Monolithic refractory lining work is simpler than bricklaying and can even be performed by relatively inexperienced workers. This makes it easy to mechanize and automate much of the furnace construction/maintenance work.
2) Monolithic refractory linings minimize the work of removing old refractory linings and permit the adding of a new lining at some later time.
3) Waste refractory materials can be recycled.

Thus, monolithic refractory lining work helps reduce labor, prolong equipment life and cut refractory material costs.

In integrating the refractory maintenance work, we discussed

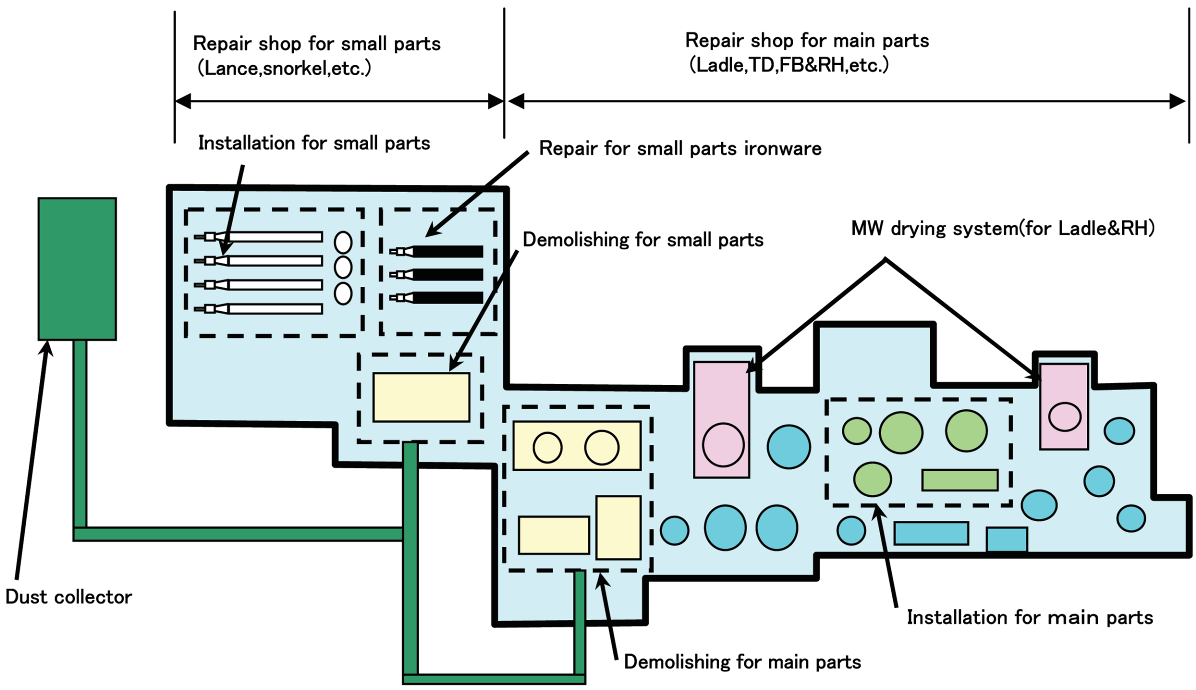

Fig. 2 Outline of refractory repair shop

applying monolithic refractory, as opposed to refractory bricks, to four types of equipment: Immersion free-board for hot metal pretreatment (FB), hot metal ladles, molten steel ladles and RH vessels.

Compared to brick constructions, monolithic refractory constructions, which are solid, are susceptible to thermal spalling, such as cracking caused by stress concentration, and to structural spalling, such as deterioration caused by slag penetration and excessive sintering. Therefore, it is necessary to ensure its structural stability. Besides, generally speaking, monolithic refractory is less durable than brick and hence, it is necessary to improve its durability. In order to ensure sufficient structural stability, it was necessary to develop a new type of joint to replace the conventional brick joint so as to restrain the occurrence and propagation of cracks and improve the volume stability.

As measures to improve the structural stability of monolithic refractory, we studied: (1) forming micro-cracks in the refractory by using raw materials with a different expansion coefficient and coarse grains, and (2) adding wire, agalmatolite, and carbon, etc. to the refractory. In order to improve the durability of monolithic refractory, it is vital to make the refractory structure denser. Therefore, we discussed: (1) adding ultra-fine particles of cement and other materials, (2) using raw materials with good corrosion resistance (spinel, magnesia), and (3) implementing highly efficient drying (microwave drying, etc.) of the dense material (**Fig. 3**).

4.2 Outline of technology for applying monolithic refractory

As an example of the application of monolithic refractory to equipment for handling molten steel, the refractory for RH degassing equipment is described below. When it comes to applying monolithic refractory to RH degassing equipment, it is important to ensure sufficient corrosion resistance of the refractory. In order to increase the density of the material and improve the material resistance to FeO, we added ultra-fine particles of alumina to the raw material and optimized the proportion of spinel in the raw material.[1)] **Fig. 4** shows the relationship between the content of ultra-fine particles of alumina and the average diameter of pores in a refractory structure. On the basis of this relationship, we adopted 4a% as the content of ultra-fine particles of alumina to make the refractory as dense a possible. In addition, in order to improve the FeO resistance of the refractory, we studied the relationship between spinel content and FeO resistance using two types of spinel (Type A and Type B). The study results are shown in **Fig. 5**. It was found that Type B spinel improved the resistance to FeO more effectively than Type A, which is used for molten steel ladles. Therefore, we developed a new material with 20% Type B spinel added.

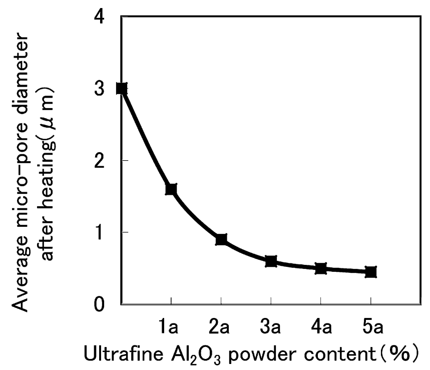

Fig. 4 Relationship between the content of ultra-fine particles and the average diameter of micro-pore in a refractory

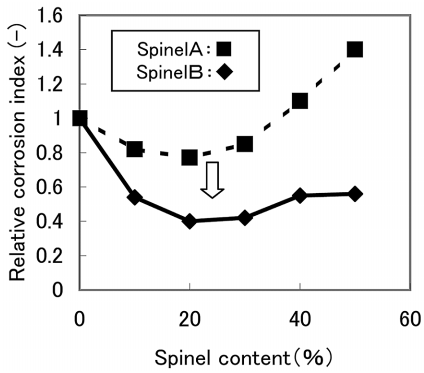

Fig. 5 Relationship between the spinel content and the corrosion resistance

5. Pressing Ahead with Further Mechanization and Labor Saving (Step II)

At the Oita Works, on the basis of the technological developments to expand the application of monolithic refractory (Step I), we

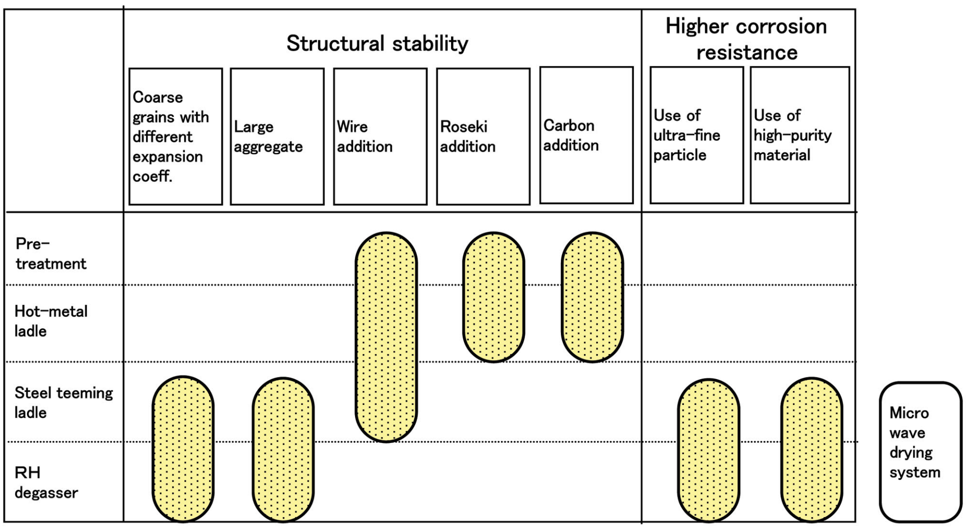

Fig. 3 Viewpoint of monolithic technology for each facility

pressed ahead with various improvement measures with the emphasis on the mechanization/automation of refractory maintenance work,[2] and complete enclosure of the waste refractory materials (zero emissions) in order to carry out drastic innovations in the refractory maintenance work (Step II). The concepts underpinning Step II are presented in **Fig. 6**. In carrying out Step II, we considered the following as the major challenges.

1) Reduction of labor in monolithic refractory casting work and speeding up the process
2) Streamlining of the physical distribution
3) Automation of the welding operation
4) Mechanization and improved efficiency of the waste material recovery work.

The development of technologies aimed to meet the above challenges is described below.

5.1 Technologies for reducing labor and speeding up monolithic refractory casting work

In the monolithic refractory casting work in Step I, the core setting operation required much time and labor because the core had to be secured with bolts. Furthermore, the mixing of the raw materials and casting of the mixture were inefficient batch operations using flexible containers to transport raw materials and a traveling mixer. As measures to improve the above conditions, we equipped the core with a self-aligning capability and adopted a core fitting and removing mechanism of flexible construction, thereby making it possible to reduce labor in the core setting operation. For the material mixing and casting operations, the flexible containers used to transport raw materials were replaced with steel containers and the conventional mixer was replaced with a dual system of high-speed, double-axle mixers.

In addition, for the transportation of mixed raw materials, a dedicated hopper car system was adopted. With the establishment of the new technology based on this system, we could achieve appreciable saving of labor and speed-up the operation from the transportation of raw materials to the mixing and casting of raw materials. **Fig. 7** shows the concept of the casting work in Step II taking the large equipment maintenance shop as an example. The salient characteristic of the working equipment in Step II is that the carrier cars are separated from the mixer. This has made it possible to perform the material transportation, mixing and casting operations concurrently. Hence, the entire process has been sped up. The hopper car can automatically be moved to any position by an address system using the X-, Y- and Z-axes. In addition, the automatic cleaning function added to the mixer allows for continuous casting of different types of raw materials. For the addition of waste refractory materials to monolithic refractory, the prescribed amount of each type of waste material to be added is automatically pre-weighed and supplied to a steel container.

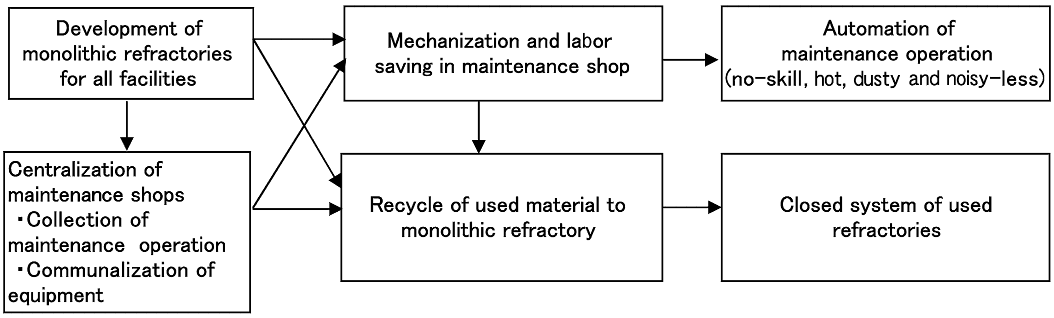

Fig. 6 Standpoint of mechanization and labor saving of maintenance shop

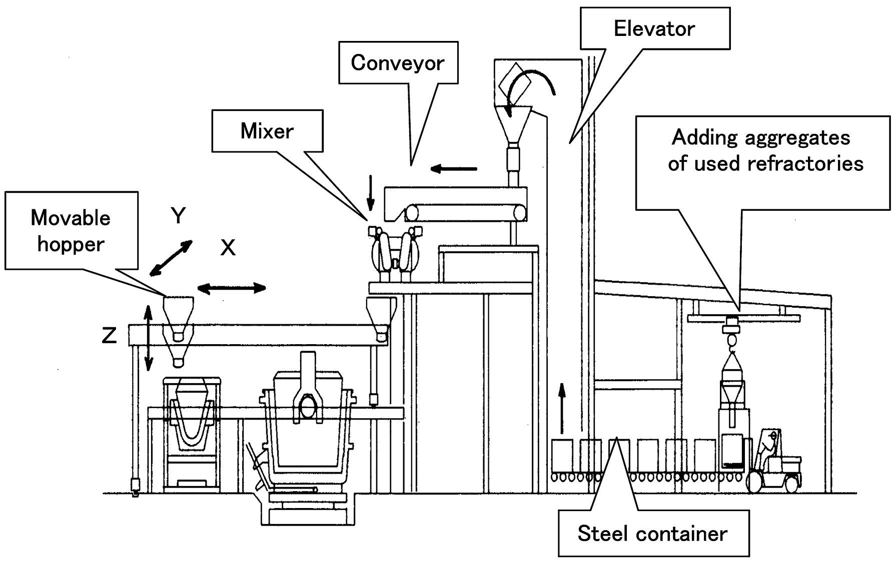

Fig. 7 Outline of casting machine

Through the efforts in Step II described above, we could achieve the following improvements on the conditions in Step I:

1) The manpower requirement was reduced from 4 - 5 staff per crew to 1 - 2 per crew.
2) The working time was shortened by about 60% for the core setting operation and by about 80% for the casting operation.

5.2 Streamlining the physical distribution

The burdensome work involved in slinging RH, FB and torn-down refractory for large equipment and in transporting lances and other small parts was identified as a matter calling for improvement. As improvement measures for large equipment, we adopted an electric motor to turn the crane hook and a motor-driven slinging device with four movable slinging jigs so as to facilitate access to sling points that differ from one type of equipment to another. This has contributed to the saving of labor in slinging operations. As for lances, arrangements were made so that several lances could be transported and dried on a dedicated platform at once. This has reduced the frequency of handling lances.

5.3 Automating the welding operation

The stud metal welding operation that took much time and labor was a problem in terms of its workload and efficiency. As an improvement measure, we developed new technology for automating the welding operation and applied it to a practical welding machine. This machine is a magnesium carbonate arc welder provided with a double torch to improve the welding efficiency. It is capable of welding two types of y-shaped studs. Studs are supplied to the welding machine by a device consisting of a vibrating ball and a linear feeder. The introduction of this welding machine has made it possible to automate the welding of studs of molten iron pretreatment immersion tanks.

5.4 Mechanization and improved efficiency of waste refractory recovery work

Concurrently with the mechanization and automation of the refractory maintenance work, we improved the efficiency of waste refractory recovery and sorting operations. Formerly, waste refractory materials were separated into base metal and refractory onsite, and only refractory pieces of a certain size were collected manually. Those refractory pieces were then put into a crushing machine and made into a product. Under this method, picking up pieces of waste refractory materials required a good number of workers and the waste recovery rate for refractory material was not very high. As improvement measures, we arranged for the waste refractory materials which occur on the integrated refractory stripping ground to be temporarily stored in a recovery yard dedicated to each type of equipment, where they are roughly separated into pieces of base metal and refractory at one time. In addition, we introduced equipment that crushes and screens sorted waste refractory materials. Thanks to the streamlined waste refractory recovery work and the efficient crushing and screening equipment, the number of staff required for the recovery work could be reduced from 4 to 2, while the recovery rate increased appreciably.

The addition of waste refractory material to monolithic refractory influences the workability, corrosion resistance and strength of the monolithic refractory. Therefore, we carried out laboratory tests to determine the range of particle sizes and the amount of addition appropriate to each type of monolithic refractory so that they could be applied to actual equipment. Today waste refractory material is widely used as a shotcrete material to repair mixing cars, a casting material for lances, molten steel ladles, and tundishes, and so on. Thus, it contributes to the reduction of refractory material costs.

6. Effects

6.1 Reduction of labor

In Steps I and II, we implemented various measures to cut down on the labor involved in refractory maintenance. As a result, we obtained appreciable benefits as shown in **Fig. 8**. The expanded application of monolithic refractory lining and the integration of maintenance shops in Step I brought about a 45% saving in labor as compared with the level before execution of Step I. The mechanization of refractory maintenance work and the saving of labor in Step II further contributed to the laborsaving benefits—47% compared to the level in Step I. Looking at a breakdown of the laborsaving effect achieved in Step II, the contribution of improvements in maintenance work is most conspicuous (47%). The total saving in labor achieved through Steps I and II is as much as about 70% compared to the prior level.

6.2 Reduction of refractory material costs

The addition of waste refractory material to monolithic refractory material was initiated in Step I, which aimed to expand the application scope for monolithic refractory lining. In Step II, the addition of waste refractory material increased by improving the recovery rate for waste refractory material. As a result, the utilization rate

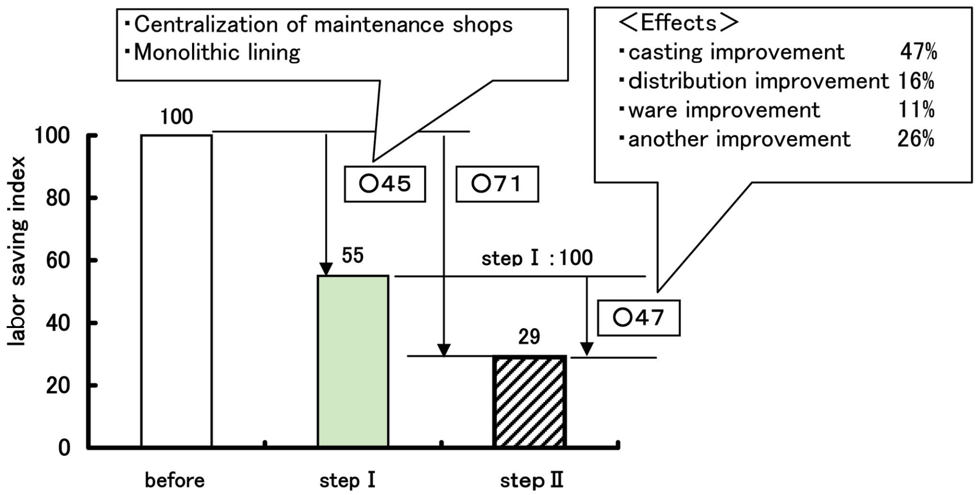

Fig. 8 Labor saving effect

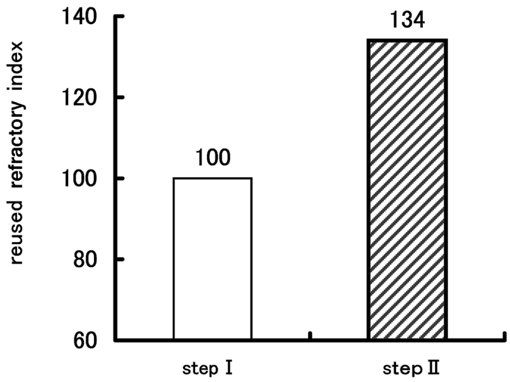

Fig. 9 The amout of reused refractory

for waste refractory material improved by 34% from Step I as shown in **Fig. 9**. The contribution of the reduction in refractory material costs made possible by effective utilization of waste refractory material is equivalent to about 5% of the total cost of the refractory materials used with the steelmaking equipment.

7. Conclusion

At the Oita Works, on the basis of the achievements in Step I (integration of the refractory maintenance shops, etc.), we pressed ahead with mechanization and automation of the maintenance work with the aim of further enhancing operational efficiency and reducing labor. As a result, in Step II, we could achieve a 47% saving in labor from Step I. The total labor saving benefits through Steps I and II comes to 71%. Refractory costs were also reduced significantly as the waste utilization rate for refractory materials increased by 34% from Step I.

References

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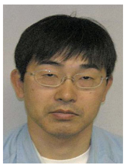

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