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Short Term Revamping Techniques of Blast Furnace

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No. 3 blast furnace (BF) at Mizushima Works and No. 5 BF at Chiba Works of Kawasaki Steel Corp. were relined in 1990 and 1991. The revamping were performed in the shortest period possible, with required times of 111 and 98 days, respectively. To complete the relining work in such short periods, several methods and techniques were developed and employed. Work on the BF proper, which was the critical part of the relining, was carried out as follows: (1) simultaneous work on separate multiple stages, (2) prefabrication of the BF shell, (3) thin wall construction of the shaft refractory material, and (4) mono-construction of the stave cooler and refractory material. Work for the material charging equipment at the BF top, which also affected the relining period, was carried out as follows: (1) large-block construction method, and (2) light weight supporting structure for hoppers. In addition, a well-organized administration system was developed and employed to ensure effective control of the relining work and manpower. As a result, the relining work was performed in the shortest possible period as planned and lost in production of both BFs was minimized.

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1 Introduction

Since its No. 1 blast furnace built at Chiba Works in 1953, Kawasaki Steel has completed a total of 10 blast furnaces construction and 19 revamping projects at Chiba and Mizushima Works mainly by its own engineering teams. One of the objectives of this series of construction and revamping work was to complete the tasks in the shortest possible period from planning to blowing-in. At present, three large blast furnaces are in operation at Mizushima and two at Chiba. In the revamping of Mizushima No. 3 BF in March 1990 and of Chiba No. 5 BF in September 1991, the shortening of the revamping period was a particularly important task. For 11 years since 1980 Kawasaki Steel had no full-scale revamping, and during this period a great change took place involving the environment of blast furnace revamping; a rapid rise in work safety control, stringent requirement for work quality, decrease in the number of revamping contractors, and general aging trend of construction workers.

This paper reports the techniques employed to solve these problems and shorten the revamping period.

2 Outline of Revamping Work

The equipment specifications of the Mizushima No. 3 BF (for the third campaign) and Chiba No. 5 BF (for the fourth campaign) are given in **Table 1**. As shown in **Table 2**, the revamping periods were relatively short; 111 days for Mizushima No. 3 BF, and 98 days for Chiba No. 5 BF.

2.1 Mizushima No. 3 BF (Third Campaign)

The inner volume of the furnace was increased in this relining and, at the same time, modern equipments

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Table 1 Specifications of Mizushima No. 3 BF and Chiba No. 5 BF

Item	Mizushima No. 3 BF	Chiba No. 5 BF
Inner volume (m^3)	4 359	2 584
Top pressure (Pa)	30×10^4	20×10^4
No. of tuyeres	36	30
No. of tap holes	4	2
Hearth brick	Carbon (6 layers)	Carbon (4 layers)
	High-alumima (1 layer)	High-alumima (2 layers)
Brick (bosh to shaft)	SiC brick	SiC brick
Cooling device	Spray (hearth)	Spray (hearth)
	Stave & cooling plate	Stave & cooling plate
Furnace top	Bell-less type	3 bells type

Table 2 Construction scale

	Mizusihma No. 3 BF	Chiba No. 5 BF
Revamping period (d)	111	98
Dismantled weight (t)	22 200	8 096
Erection weight (t)	13 477	7 204
Labor (man-hour)	1 157 000	56 400

were installed to reduce the hot metal cost and extend the life of the furnace. The principal modifications are enumerated below.[1]

(1) The inner volume was increased from 3 363 m^3 to 4 359 m^3.
(2) The furnace shell, staves and refractories were all replaced with new ones.
(3) Staves were newly installed in the upper shaft.
(4) The bell-type furnace top equipment was replaced with the 3-bunkers bell-less type.
(5) The cast-house floor was made flat to improve the working environment.
(6) Cast-house operation was mechanized and automated to save labor.
(7) Heat holding control of the hot stoves was used and the hot-stove valves were repaired.
(8) Size-control equipment was newly installed in the material discharging system.
(9) The control room was totally changed and CRT operation was introduced.
(10) The slag granulation system was completely modified.

2.2 Chiba No. 5 BF (Fourth Campaign)

A simple modification only to renew equipment deteriorated was the basic policy. For this reason, the inner volume was not changed, and the production capacity and functions of the equipment remained the same as those before relining.[2]

(1) The damaged furnace shell of shaft was renewed.
(2) The plate under the hearth was completely renewed to prevent gas leakage.
(3) The wearing plates at the throat were reused and protectors were newly installed in the worn areas.
(4) The staves, cooling plates and refractories were all replaced with new ones.
(5) Staves were newly installed in the upper shaft.
(6) The stave cooling water was changed from circulating water to forced-circulation of pure water.
(7) The top charging equipment was overhauled in the workshop and reused.
(8) Part of the cast-house floor structure was changed from concrete with notable deterioration to steel frame.
(9) For the electrical and instrumentation equipment, the CPU was renewed and CRT operation was introduced.
(10) Heat holding of the hot stoves was used.

3 Techniques Applied for Short-Term Revamping

3.1 Total Engineering for Short-Term Revamping

As shown in **Fig. 1**, a satisfactory completion of short-term revamping calls for an early planning for specific construction methods and a lining up of workpiece requirements so as to determine a total revamping period, all of which will be fed back to equipment designing. It is also necessary to make an early start of construction prior to blowing down so as to reduce work load during the main construction stage. Main construction methods used in the revamping were simultaneous construction method, major block construction method and prefab construction method.[3]

3.2 Blowout and Dismantling

To minimize salamander and scab that have a drastic effect on the dismantling process, the inner walls of the furnace were cleaned during operation and "empty-furnace blow-out" was used to empty the furnace above the tuyere level. Furthermore, the hot metal remaining on the hearth was removed through temporary tapholes and runners to reduce the dismantling volume. Before the blow-out, the hearth brick wear line was estimated by the boundary element method and the salamander volume was predicted. In Mizushima No. 3 BF, two temporary tapholes were installed. At one of the two tapholes, continuous hot metal receivers were provided for three torpedoes, and hot metal was continuously received in the three torpedoes without a runner change. At the other taphole, a runner for pouring hot metal into an emergency sandpit was installed.

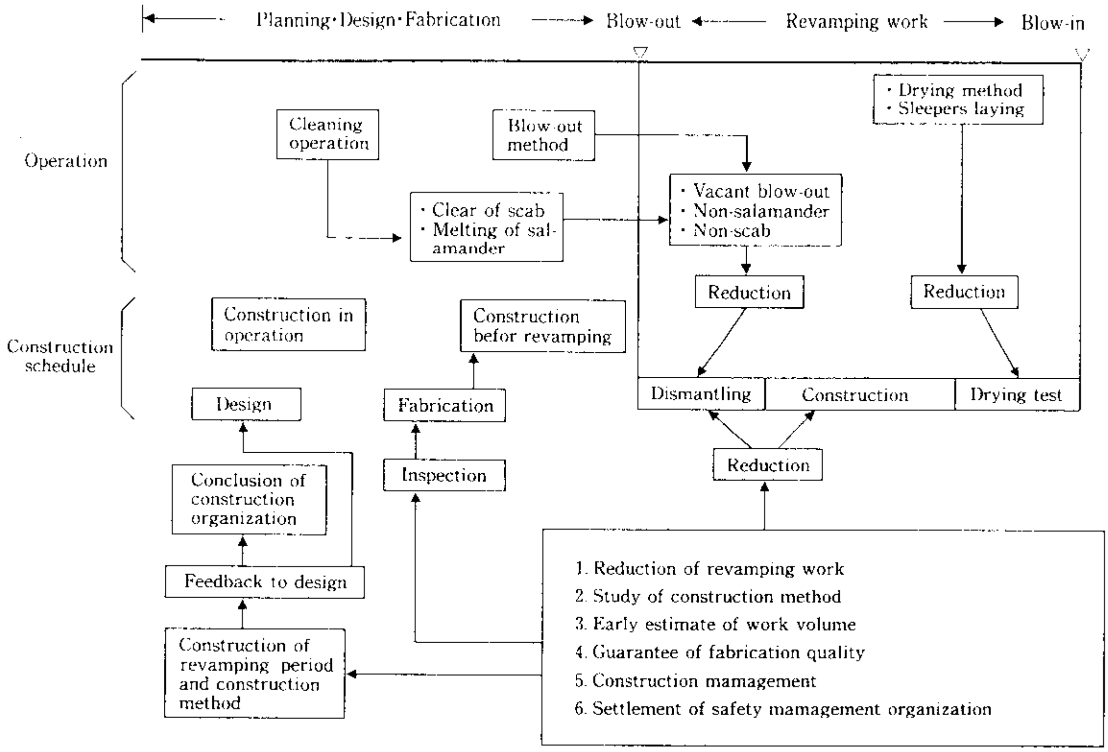


Fig. 1 Total engineering of short term revamping

3.3 Simultaneous Construction Method Covering Multiple Stages

The installation of a lower safety ceiling, an upper safety ceiling and a covering deck in the throat allowed the simultaneous work on the following four stages:

(1) Installation of the top charging equipment
(2) Work in the shell from the top ring to the upper shaft (installing wearing armors, laying of shaft bricks, etc.)
(3) Work in the shaft shell (installation of staves, laying of shaft bricks, etc.)
(4) Work in the hearth shell (laying of hearth bricks, etc.)

The provisions to enable simultaneous construction method covering four multiple stages is shown in **Fig. 2**. Equipment that was as light as possible was used, and reuse of relocated equipment and the use of multifunction equipment contributed to the short revamping period.

3.4 Installation of the Furnace Shell

Efforts were made to reduce the revamping period for relining of Mizushima No. 3 BF by increasing the size of shop-fabricated shell blocks and minimize the number of blocks installed on site. In the example shown here, the base plate at the lowest part of the furnace, hearth shell, cooling pipe of under hearth and H-

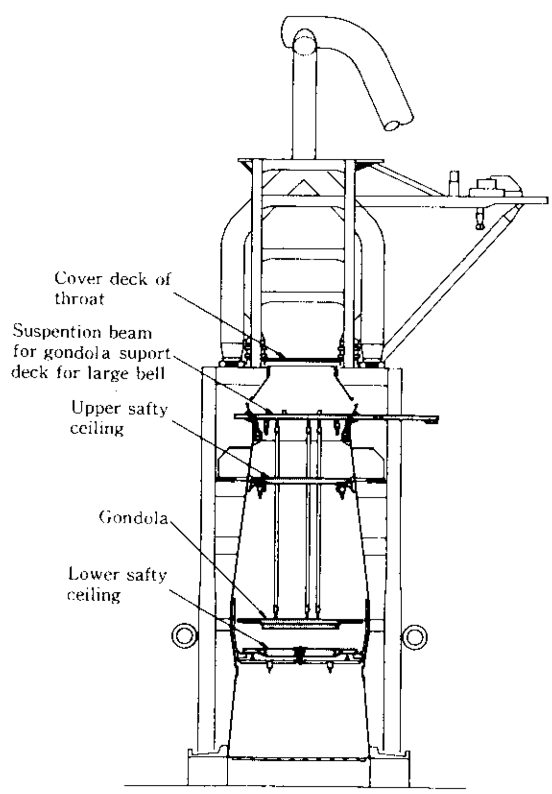


Fig. 2 Simultaneous construction

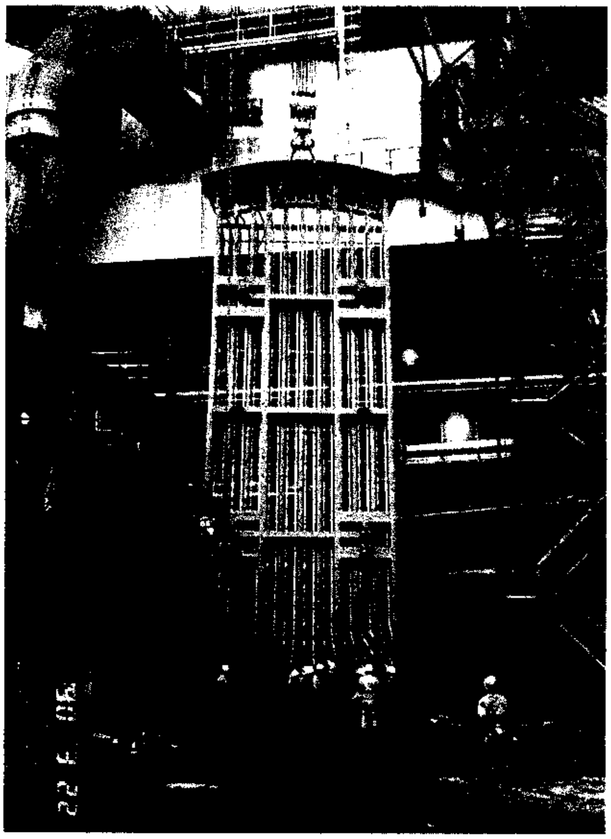


Photo 1 Erection of furnace shell

beams for supporting plate under hearth were prefabricated into one large block. **Photo 1** shows how this block was taken into the furnace. This block was 1.5 m in height, 6.4 m in width and 19 m in length and weighed 65 t. With the conventional method, the shell would be completely assembled on site. By adopting the new method, it was possible to shorten the revamping period by 5 days.

3.5 Installation of Furnace Cooling Equipment and Furnace Wall Brickwork

The reduction in on-site work volume playes an important role in achieving a short revamping period. The techniques adopted for installing the furnace cooling equipment and furnace wall brickwork in the two blast furnaces are described next.

3.5.1 Installation of furnace cooling equipment

The number of staves and cooling plates was decreased by increasing their sizes and, at the same time, the fabrication and installation accuracy of the furnace shell, staves and cooling plates was improved. An improvement in fabrication accuracy means a decrease in work volume by eliminating detail fitting and reconditioning work during assembling and installation on site. This enabled twelve hours to be saved per stage of staves, so that the revamping period was shortened by five days for the complete stave installation process.[4)]

3.5.2 Furnace wall brickwork

Thermal loads on the furnace wall ranging from the upper shaft to the throat are increased by all-coke operation. As a result, the wear of the furnace wall bricks increased, affecting the furnace condition. In the lower shaft, the furnace wall bricks fell off early and the staves broke, generating hot spots and cracks. To solve these problems, the support structure for the furnace wall brick was reinforced, thus ensuring a more stable furnace lining profile for a longer time, and the revamping period was shortened at the same time.

(1) Structure of the Upper Shaft
Staves onto which castables had been placed in the shop were installed inside furnace so that on-site installation of brickwork in the upper shaft was made unnecessary. To reduce heat losses from the upper shaft, the thermal insulation was considered and the thickness of castables in this part was set at 150 mm. The support for the castables was enhanced by adopting F-type staves.

(2) Thin-Wall Structure for Shaft Brickwork
Staves in combination with cooling plates to improve brick support function for a single layer of bricks was planned, and this structure was used in the shaft. The adoption of this technique saved some of the weight of the shaft bricks and, hence, the work volume for brickwork, shortening the revamping period by three days. The use of reinforced water-cooled staves prevented a decrease in the strength of the castings and prevented the wear and cracking of the castings; thus, the life of the staves was extended. Furthermore, copper cooling plates were arranged in four stages to strengthen the furnace-wall brick support. The furnace wall brickwork was laid in one layer of SiC bricks to give a furnace wall thickness of 380 mm, and the wear rate of the bricks during operation was reduced by the improved material quality and cooling effect. A furnace wall profile that would remain stable for a long time was ensured in this manner.

(3) Adoption of a New Cooling Device
A new cooling device (NCD) was developed to extend the life of the furnace wall by improving the cooling effect and brick support, and to shorten the installation work period. This NCD enabled the furnace cooling equipment and furnace wall bricks to be installed in one piece. The NCD was tested in an actual furnace. In actual performance, installation work was similar to the conventional stave installation, making it possible to develop technology to bypass shaft bricklaying work on site in future revamping work. The NCD has the following two features:

(a) The staves, copper cooling plates and furnace

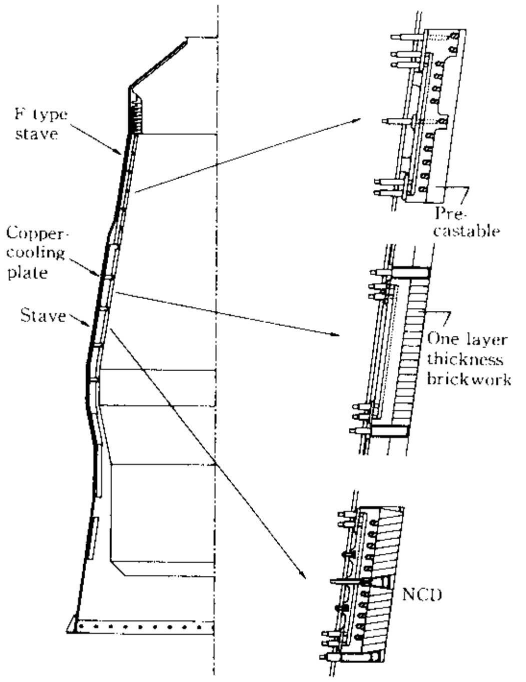


Fig. 3 Furnace cooling device

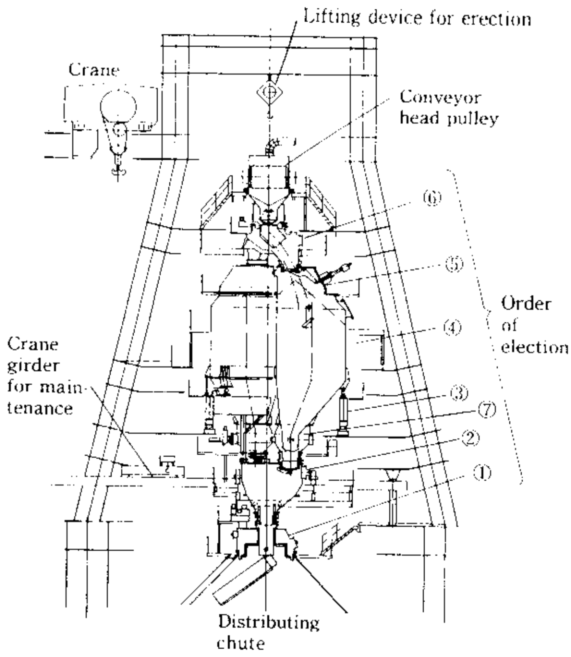


Fig. 4 Outline of the 3-parallel-bunker bell-less top for Mizushima No. 3 blast furnace

wall bricks are assembled into one unit in the workshop, and this one-piece unit is then installed on the furnace shell.

(b) The coating material for the stave pipe is much improved, aiming at the heat conductivity to be 4 to 5 times that of conventional material.

A cross-sectional view of the furnace wall construction is shown in **Fig. 3**.

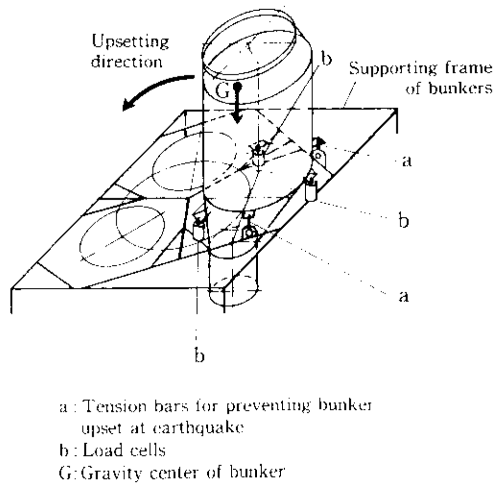
3.6 Installation of the Top Charging Equipment

3.6.1 Features of top charging equipment

The introduction of bell-less charging equipment involved a development at Mizushima No. 3 BF of the three-parallel-bunker type excellent in burden distribution controllability and flexibility of operation. This equipment is characterized by the dynamic control function of the burden flow rate-adjusting gate and by multiple-batch charging function that permits a large amount blending of small lumps of sinter and coke. The general construction of this bell-less top charging equipment is shown in **Fig. 4**. To shorten the revamping period, the equipment was designed so as to minimize the beam modification work at site by using a long bunker to house it within the existing beam structure, and a low-head seal valve developed and installed to eliminate the need for the level-raising work for the charging conveyor.

3.6.2 Bunker support structure

Because there is little space between the straight sides of adjoining bunkers, a Y-form support frame for the conical section was devised and installed. The tension bars shown in **Fig. 5** were installed to absorb the overturning moment of the bunkers during an earthquake. The maximum load from the three bunkers is 810 t, and the greater part of this load acts on the Y-form support frame. Therefore, the strength was checked by the KBSD system (Blast furnace structural analysis system developed by Kawasaki Steel). The analytical model is shown in **Fig. 6**.



a : Tension bars for preventing bunker upset at earthquake
b : Load cells
G : Gravity center of bunker

Fig. 5 Supporting device of bunkers

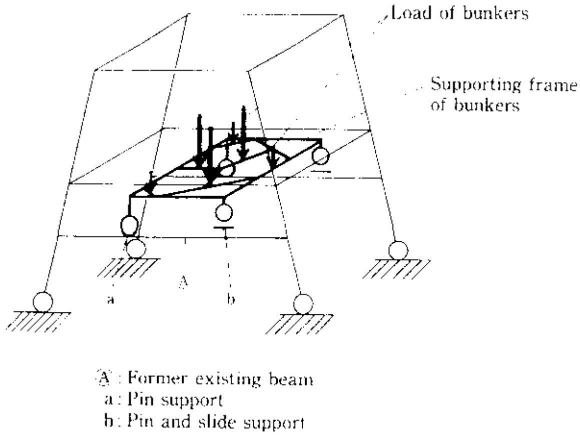


Fig. 6 Analytical model of supporting frame of bunkers

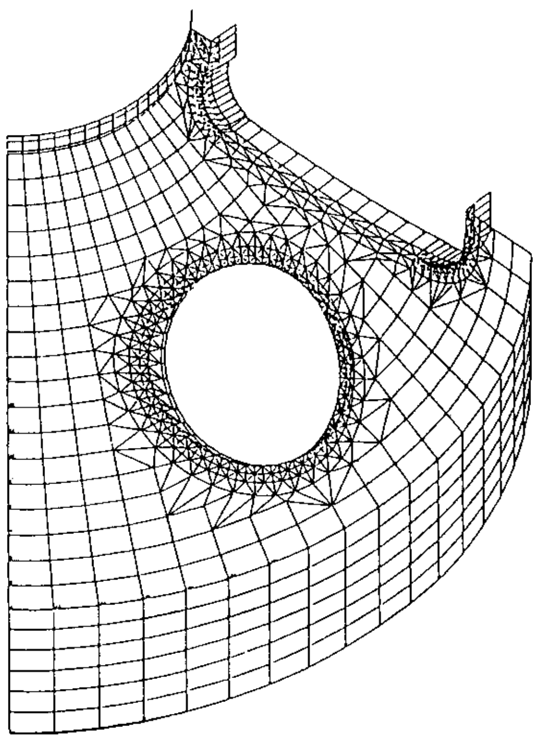


Fig. 7 Model for stress analysis of furnace top shell

This system performs a structural analysis on the furnace body and the body cooling equipment and support columns, and can automatically prepare drawings in conjunction with a CAD system. An example of an analytical model for the opening in the throat shell for the rotating charging chute is shown in **Fig. 7**.

This system is used by Kawasaki Steel as an effective tool for short-term revamping plans.

3.6.3 Method for installing the charging equipment

As much of the charging equipment as possible was taken into the furnace as one unit by using the top crane and a crane mounted on top of the upper frame. The following measures were especially effective for shortening the revamping period:

(1) Frames were modified as much as possible before the relining work.
(2) The bunker support frame was shop-assembled and taken into the furnace as a single unit on site.
(3) The bunker liners were installed before-hand to the limit of the lifting load to reduce the amount of site work.
(4) The sealing valves for the three bunkers were held together in one unit with a jig and installed on site.
(5) The travel beam for maintenance was used actively to take the equipment in.

3.7 Work Control System

To carry out revamping with a minimum number of workers in the shortest possible period, an important task was an application of system engineering for various administration work. Therefore, systems for labor safety management system, budgetary control system, work scheduling preparation system, etc. were developed to obtain data for attaining a short-term revamping work efficiency and collect engineering data for the next term revamping. These were used as construction work administration support tools. An outline of the labor safety management control system is given next.

3.7.1 Labor management and safety control system

This system controls the progress of work mainly in terms of labor management and safety by monitoring the difference between the plan and results of the blast furnace revamping schedule, manpower used, safety conditions, etc. The system is composed of six subsystems as shown in **Fig. 8**. Data generated every day are input to the computer, data necessary for work control are tabulated every day for each week and month, and output data are judged by the project staff.

3.7.2 Effect of the work control system

This system was applied to the short-period revamping work of the Mizushima No. 3 BF. As a result, it was possible to have timely information for work control, work safety control and budget control, and to take the necessary actions that would contribute to the smooth progress of the work. Furthermore, the adoption of this system resulted in a reduction of two staff persons compared with the conventional system.

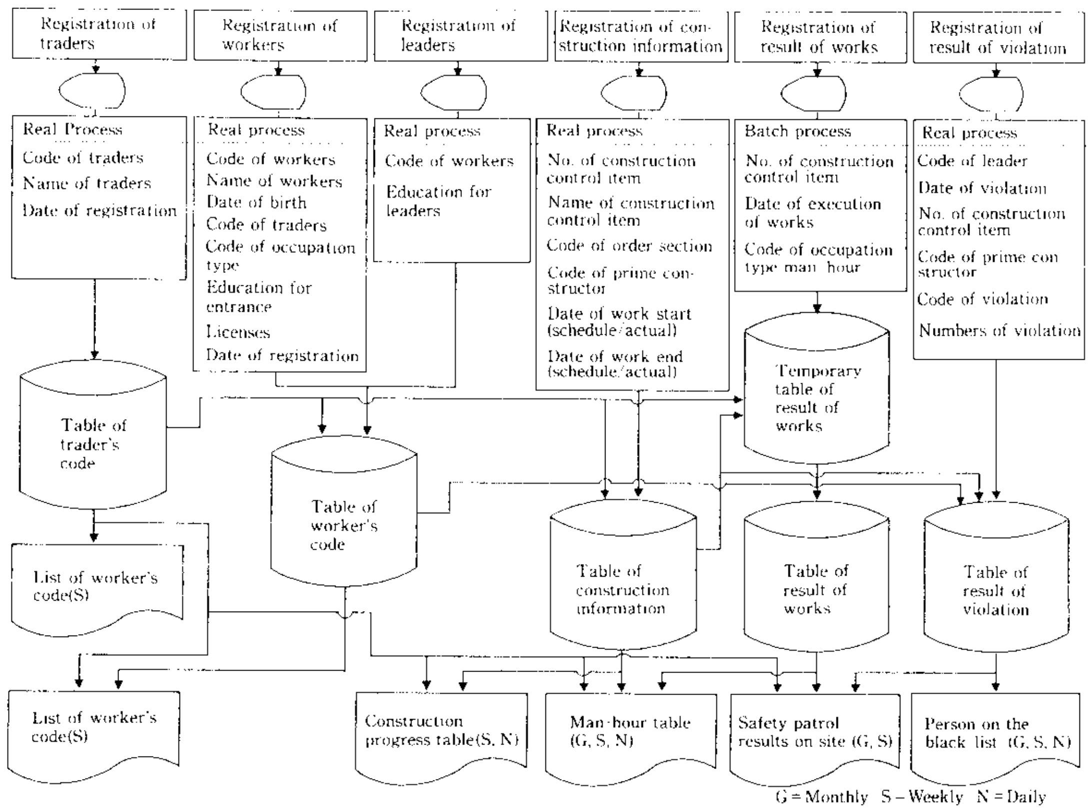


Fig. 8 General organization flame work of Blast Furnace Repair Works Control system

4 Conclusions

The techniques applied to shorten the period for revamping Mizushima No. 3 BF and Chiba No. 5 BF have been reported, and are summarized as follows:

(1) The methods for dismantling and installation have a great effect on the length of the revamping period. Simultaneous work on multiple stages, installation of large shell blocks, installation of staves and furnace wall brickwork as a single unit, and thin-wall construction for the shaft brickwork were effective for shortening the revamping period.

(2) The top charging equipment in Mizushima No. 3 BF was changed from the bell type to the bell-less type concurrently with the relining work. To shorten the revamping period, the charging equipment was designed such that the volume of modification work on the support frame was minimized and the equipment was installed in large blocks.

(3) Improved working efficiency by the staff engaged in the relining work was achieved by using a work control system developed to provide a timely grasp of the state of work.

The revamping period for Mizushima No. 3 BF was 111 days and that for Chiba No. 3 BF was 98 days. In spite of this short work period, blowing-in and start-up of both blast furnaces went smoothly and they have been operating without trouble. The revamping of other blast furnaces at Mizushima and Chiba Works of Kawasaki Steel in the future is also planned, and the necessity for short-period revamping will progressively become greater. The authors intend to improve further the techniques described in this report and apply them to the relining of blast furnaces in the future.

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