KAWASAKI STEEL TECHNICAL REPORT
No.11 (March 1985)

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Synopsis :
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The body can be viewed from the next page.

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1 Introduction

The environment of the ironmaking operation has recently changed noticeably, with increasing needs for technological improvement and reductions in the pig iron production cost. To meet these requirements, it is important to take overall revamping measures that cover not only the blast furnace section, but also the sinter and ore yard sections.

The principal jobs of the ore yard section include the unloading from ships of vast amounts of ore and coal, besides material-handling management and quality control. So far, however, systems have been insufficiently established for gathering and utilizing high-accuracy operational data to a level necessary for conducting effective process control. To solve this problem, the Ironmaking Department of Mizushima Works came to develop successively in a period from 1978 to 1983 systems for ore blending, blast furnace operation, and sinter plant operation[1]. This was followed by the start of a system development for ore yard operation which has been completed recently. This report describes functions and application condition of the ore yard system.

2 Outline of the Ore Yard System in Total Ironmaking System

Figure 1 shows the configuration of the total ironmaking system. This system consists of the three operations of blast furnace, sinter and ore yard as well as subsystems for ore blending program and general-purpose technical analysis. Functionally, this system has a hierarchical computer configuration and includes an information management system by business computers, a control system by process computers and, further, operation systems such as for CRT operation in the sinter plant.[2]

The process computer that is the nucleus of the ore yard system is connected to various microcomputers for specific purposes and various controllers by an optical fiber network, and performs control and the collection and processing of process information. The host business computer that is connected to process computers by optical fiber data highways stores various data bases necessary for process control, which are effectively utilized for analytical jobs. Incidentally, one of the features of this system is the adoption of optical fiber cables in order to prevent induction noises from various high-voltage electric units installed in the ore yard.

3 Functions of System

The functions of this system can be divided into the following four classes:

(1) Preparation of operation plans

* Originally published in *Kawasaki Steel Giho*, **16**(1984)3, pp. 155-164.

** Mizushima Works

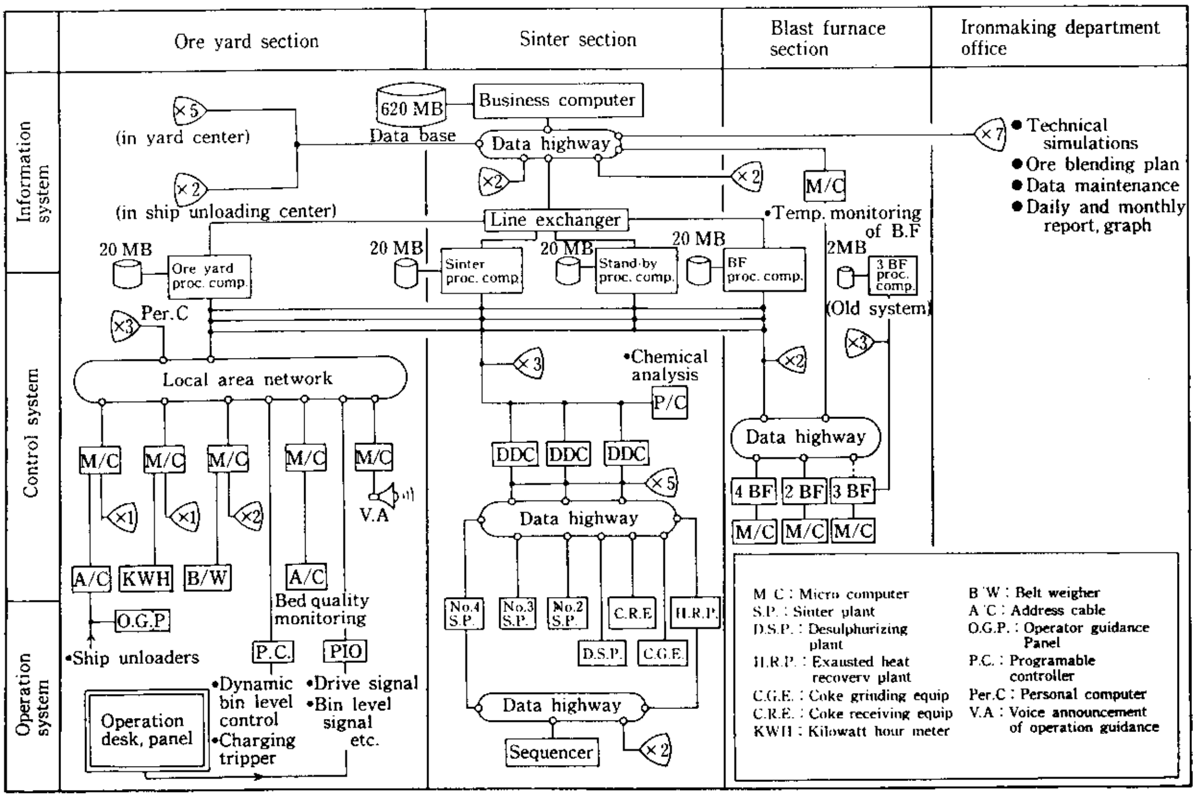


Fig. 1 Configuration of total ironmaking system

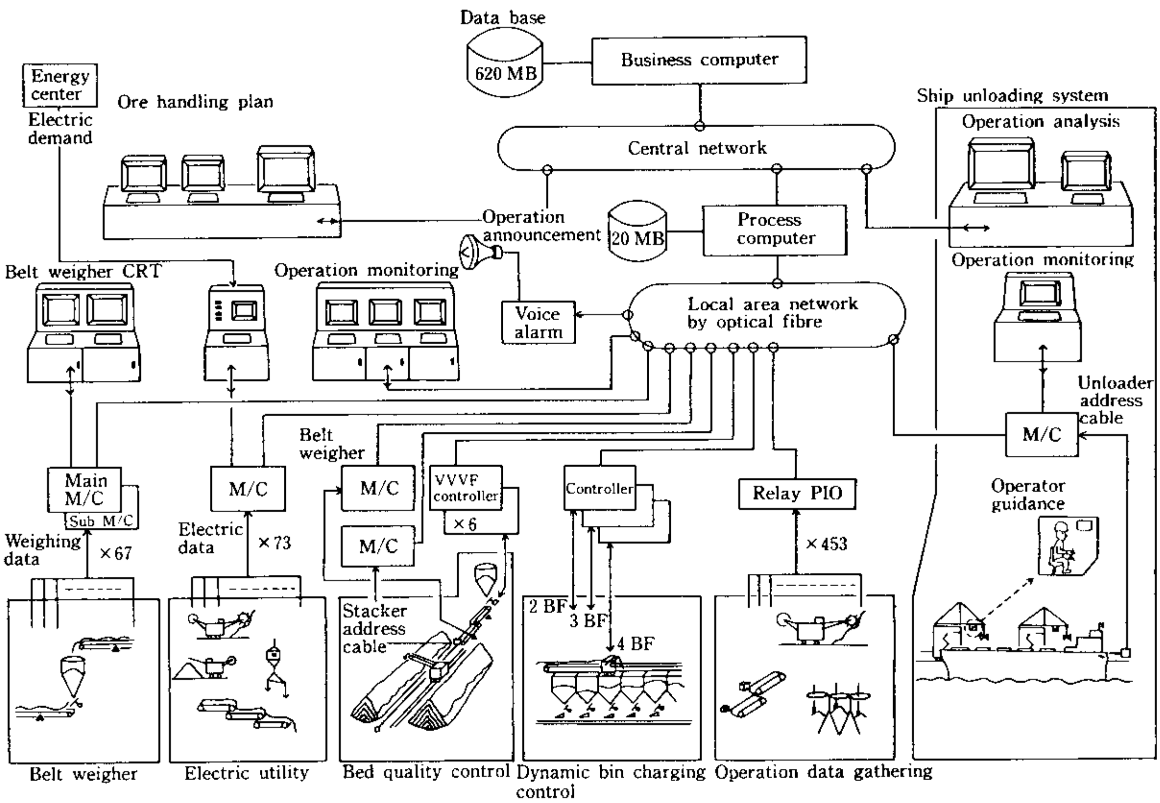


Fig. 2 Layout of ore yard system

(2) Operation and control
(3) Operation monitoring
(4) Gathering and application of actual data.

Figure 2 shows the configuration of the ore yard system. Operation plans are interactively prepared using the CRT of the business computer. Planning covers all types of jobs in the ore yard, such as for stacking and reclaiming of ore yard, bedding and sizing of ores, charging ores into and discharging from various bins.

The control system has two functions, i.e., dynamic charging control of blast furnace lump ore bins and quality control of sintering fine ore beds. The dynamic charging control aims to prevent crushing during the charging into sinter storage bins. The quality control of fine ore beds for sintering involves the stabilization of chemical composition in the longitudinal direction of beds through a constant feed control for bed stacking and the quality evaluation by a sinter bed quality monitoring system.

Operation monitoring covers the ship unloading operation at the ore and coal berths and the material transportation in the ore yard. Operation results are immediately given to operators in charge of operation and monitoring, and are used for improving the transportation efficiency.

The gathering of actual data deals with unloading and material transportation in the yard, electric data of transportation equipment, bed quality data, bin stock information, etc. These data are stored in the business computer as data bases and are used for process control in the form of operation log sheet and graph.

3.1 Preparation of Operation Plans in Interactive Mode Using CRT

The ore yard operation consists of ship unloading, ore sizing, ore bedding, ore charging into blast furnace and sinter plant bins, etc., and for these purposes many belt conveyors, stackers and reclaimers are used. Operation plans for a series of these jobs were made by skilled persons, who have performed the checking into possible interference of equipment operations, prediction of the bin stock running-out time, decision of the bin charging time, etc. all by manual calculations. There has been room for improvements, however, with respect to the standardization of preparation methods and the distribution of workload for the preparation. To solve these problems, an interactive method using the CRT of the business computer has been developed so as to computerize simple repetitive calculations and judgment toward the job standardization and higher efficiency.

This method has the following features:

(1) Automatic calculation of the time at which the ore stock reaches the lower limit in making bin charging plans.
(2) Automatic calculation of time required for transporting a planned tonnage of ores.
(3) Automatic checking into possible interference of transportation equipment in operation at one given time.

Figure 3 shows a CRT screen display of blast furnace hopper charging planning as an example of preparation in this interactive mode. In this screen, the planned operation time is indicated on the abscissa, and the blast furnace charging hopper number on the ordinate. This screen covers from No. 1 BF to No. 4 BF. The symbol "C" in this screen indicates that the ore "P · PR-L" (abbreviation) in the No. 3 BF hopper reaches the lower stock limit at 4:00, that the stock weight at that time is 389 t, and that the charging availability up to the upper stock limit is 580 t. Based on these displays, person-in-

```
84-06-08 15:59:02
 84 年  6 月  8 日    ◆◆  日間高炉貯鉱槽計画  項目入力画面  ◆◆
 次計画開始時刻   8 日 20 時
 槽名 銘柄   処理量ヤード  機器 装入変更槽   NO.  銘柄   槽名 槽数 在庫量 装入量
 1BFH                                     | C    P.PR-L 1BFH
 2BFH                                     | 槽在庫要求  2BFH
 3BFH P.PR-L   500  MS2Y  MS2SR           | 時刻        3BFH 1     389     580
 4BFH                                     | 銘柄        4BFH
                   20°   21°   22°   23°   0°    1°    2°    3°    4°    5°
                   +-----+-----+-----+-----+-----+-----+-----+-----+-----+
   1 高炉貯鉱槽     *:::::*:::::*:::::*:::::*:::::*:::::*=====*:::::*:::::*


   2 高炉貯鉱槽     ---->:*::::<-->:<>*:::::*:::::*:::::*=====*:::::*:::::*
                   -L          P.SV-SS-L                                F
                               420   160
   3 高炉貯鉱槽     *:::::<--->:*<->::*:::::*:::::*::S::*=====*:::::*:::::*
                        P.SV-L SS-L                               C
                        480    240
   4 高炉貯鉱槽     *:::::*:<--->::<--->:<------>:*:::::*=====*:::::*:::::*
                          SS-L   P.SV-LA.006
 確認区分                 420    560   1010
 次処理指定 = (    )         ? C    ? N                             & ENTER
 =>                                                              NS
```

Fig. 3 Interactive CRT display of BF hopper charging planning for data setting

Photo 1 CRT operation planning of ore yard handling

charge of planning programs charging timing before the lower stock limit is reached. In this screen, the charging weight is 500 t, the reclaiming yard is "MS2Y" (abbreviation), and the reclaimer is "MS2SR" (abbreviation). As such, all inputs are made in abbreviation.

The symbol <---> indicates the duration of operation. When the person-in-charge of planning puts in the start mark S or the end mark E, the length of operation time is automatically calculated from the standard transportation efficiency previously stored in the computer and is displayed on the screen. Ore yard operation plans are all interactively made by the above-mentioned method. **Photo 1** shows the interactive CRT operation by this method.

Algorithms for making a schedule for ore yard belt conveyor operations have been examined in various aspects as a suitable theme for operations research using computer. Some of them show considerably advanced mathematical techniques; in application, however, they do not always yield good results. It may safely be said that the value of systems used in the operation field depends entirely on how rapidly the system can deal with various unexpected disturbances such as equipment troubles and changes in ship on-berth schedules. Moreover, it is necessary to develop programs in such a way that they can be developed into software without difficulty and that the software can be maintained easily. In developing this interactive mode by CRT, past system developments were examined, and the knowledge and experiences accumulated for many years by skilled persons-in-charge of planning were thoroughly taken into consideration. Simple repetitive calculations and judgments were shifted from the job of man to that of computer. As a result, a very flexible system has been developed in which the advantages and disadvantages of man and computer are interactively covered up with each other.

3.2 Monitoring of Ore Yard Operation

This monitoring covers the overall operation progress, conveyor belt weigher functioning and bin stock level.

3.2.1 Monitoring of operation progress

In the ore yard, various operations such as ore sizing, ore bedding and bin charging must be carried out without delay according to a given plan, and operators are required to skillfully select or change conveyor routes. In this system, multiple pieces of information on conveyor operation and raw material conveying and weighing are collectively displayed on the CRT of the process computer to make monitoring efficient. **Photo 2** shows an example of this monitor screen display where all jobs, planned, in-process, or ended, are shown in time series to facilitate the schedule control.

3.2.2 Monitoring of material conveying and weighing

To maintain the tonnage of materials to be conveyed exactly at a level planned is very important for increasing the accuracy of ore blending planning. Accumlative and instantaneous tonnages obtained by belt weighers installed over the ore yard are collectively displayed on the CRT of the microcomputer, thus centralizing the monitoring of material conveying and weighing.

3.2.3 Bin stock monitoring

Stock calculations of blast furnace ore bins and sinter plant fine ore bins are automatized by using the process computer. By so doing, the accuracy of stock control was increased and labor was saved concerning the estimation patrol of stock amounts. **Photo 3** shows an example of this monitor screen display.

There are two methods of measuring bin stock: the incoming/outgoing balance calculation method by measured values of belt weigher and the level measurement method by the ultrasonic level meter or the sounding meter. Under the level measurement method, errors by using the specific weight of material are apt to occur when converting volumes into weights. Furthermore, the measurement range on the material surface is narrow and obtained data lack representativeness. Therefore, the incoming/outgoing balance calculation method was adopted in this system. To eliminate weighing errors, an automatic stock level calibration is conducted using signals from upper limit detecting switches installed in each bin. The accuracy of data is improved in this manner.

3.2.4 Operation monitoring by voice alarm (loudspeaker)

The above-mentioned various methods of operation monitoring are based on the use of CRT. In addition to them, operation monitoring and guidance by voice alarm are developed in which the hearing of operators is

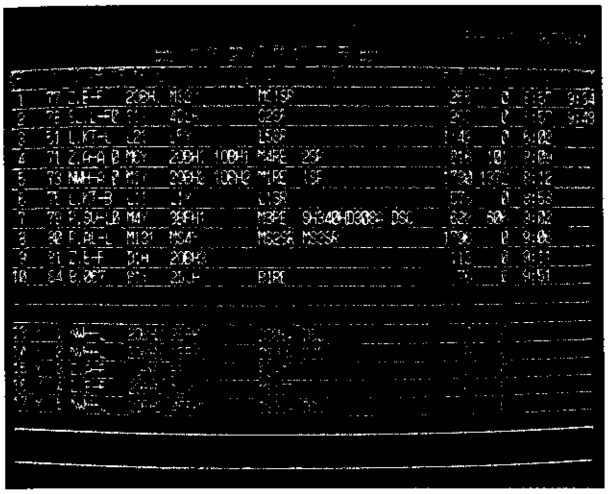


Photo 2 Schematic monitor of ore yard handling (CRT display)

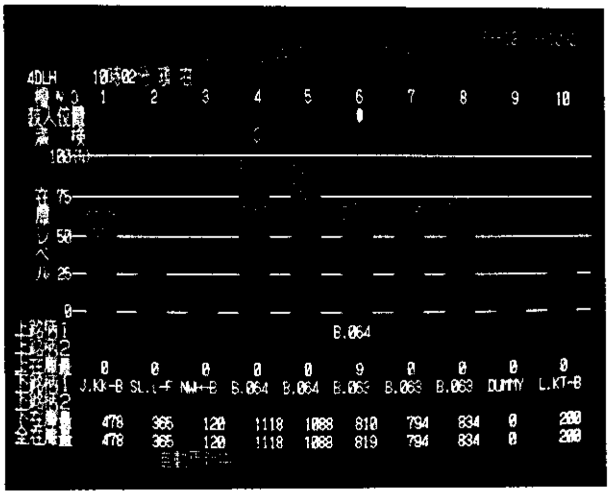


Photo 3 CRT display of BF hopper level

utilized. The starting of voice alarm is performed by the process computer and bin stock levels below the lower limit, idling of conveyors, predicted balance of demand and supply of sinter, etc., are notified over a loudspeaker.

3.3 Quality Control of Sintering Fine Ore Beds

To produce sinter of stable quality, it is necessary to conduct thorough quality control of the ore bedding process.[3] The bed quality control of this system involves the formulation of optimal bedding schedules by ore bedding models, homogeneous bedding control in the stage of bed stacking, and quality assessment of chemical composition by a sinter bed quality monitoring system.

3.3.1 Formulation of optimal bedding schedules

At Mizushima Works, about 25 to 35 brands of ore are stacked to form fine ore beds. Bed reclaiming is conducted using a double wheel type bed reclaimer. It is known that variations in chemical composition during bed reclaiming are greatly affected by the bedding order of multiple brands of ore. There is an optimal bedding order for keeping a stable chemical composition of sinter.

In consideration of the above-mentioned point, simulation models have been developed for predicting chemical composition of fine ore reclaimed from beds, and a principle for determining an optimal bedding order has been discovered. After that, bedding schedules are automatically prepared using the business computer. The ore bedding models and the principle for determining the bedding order are outlined in the following:

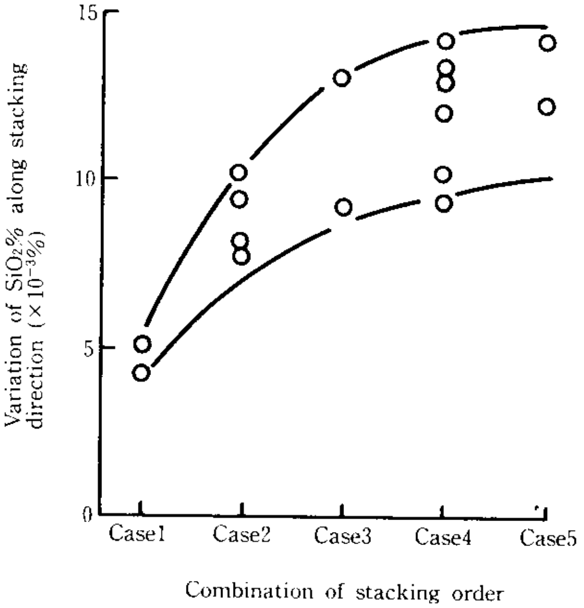
(1) Simulation by longitudinal model of bed
This model is used to simulate variations in chemical composition of an ore bed in the longitudinal direction when multiple brands of ores with different chemical compositions are continuously stacked. As a result of various simulations, it was found that the chemical composition in the longitudinal direction can be kept stable if the ore bedding order is determined to be such that the feed amount of a specific control element (such as SiO_2) increases or decreases successively. **Figure 4** shows results of simulation by this model. By changing the bedding order of five brands of ores with different SiO_2 contents, variations in SiO_2 in the longitudinal direction are the smallest in Case 1.

(2) Simulation by cross section model of bed[4]
This model is used to simulate variations in chemical composition when a bed is reclaimed in the width direction using a double wheel type bed reclaimer. In the first half bedding period corresponding to about 40 to 45% of the total stacked weight of the bed, the brands of ore whose chemical composition is as close as to the average controlled content of the bed are preferentially bedded. Conversely, in the latter half period, the brands of ore whose chemical composition is far from the average controlled content are stacked. It has been found that this procedure can keep chemical composition stable.

The results of (1) and (2) described above have been collectively examined to formulate a system for bedding scheduling. As a result, the workload was lightened of planning and the chemical composition of sinter was made stable.

3.3.2 Homogeneous bedding control

(1) Constant feed control of ore bed bin
Ensuring a stable feed amount from the ore bed bin located in the upstream part of the ore bedding process is a prerequisite to a uniform stacking in the longitudinal direction of the bed. The ore bed bin constant feeding which was recently adopted func-



Case 1: + + + +, − − − −
(BCADE)(EDACB)
Case 2: + + + −, − + + +, + − − −, − − − +
Case 3: + + − −, − − + +
Case 4: + − − +, − + + −, + + − +, − − + −,
− + − −, + − + +
Case 5: + − + −, − + − +
+: Increase of SiO_2
−: Decrease of SiO_2
Kind of ore: A, B, C, D, E
Content of SiO_2: A = 5%, B = 0%, C = 4%, D = 8%, E = 12%

Fig. 4 Effect of bed stacking combination on variation of SiO_2% along stacking direction

tions the control of revolutions of the electric vibrating feeder (VVVF control). Compared with the constant feed weigher, this system is favorable in terms of construction cost at the same feeding accuracy.

(2) End-point bedding control

When multiple brands of ore are continuously stacked, the conjunction between two different brands occurs randomly in the longitudinal direction of the bed, thus causing variations in chemical-composition in this direction. To eliminate these variations, a control method was developed by which the conjunction between two brands of ore agrees with both ends of the bed in chemical composition. **Figure 5** shows an example of calculation that shows the effect of this control method. As is apparent from this figure, variations in SiO_2 in the longitudinal direction of the bed decrease from 0.018% to 0.002%.

3.3.3 Bed quality monitoring

Figure 6 shows the configuration of the bed quality monitoring system. The bed stacker position is detected at 1 m interval using an inductive address cable. The weight of stacked bed are determined by processing signals from the upstream belt weigher using a tracking program of conveyor. Chemical compositions are calculated from data on stacked weight distribution in the longitudinal direction of the bed for each brand of ore to evaluate variations in chemical composition. Furthermore, variations in chemical composition during reclaiming are predicted using the cross section model of bed. The bed quality is quantitatively evaluated from these pieces of information, which, as ore quality information, also serve for sintering operation.

Figure 7 shows the stacked weight distribution in the longitudinal direction of the bed when 82 000 t of ore is stacked into a 250-m long bed using a bed stacker.

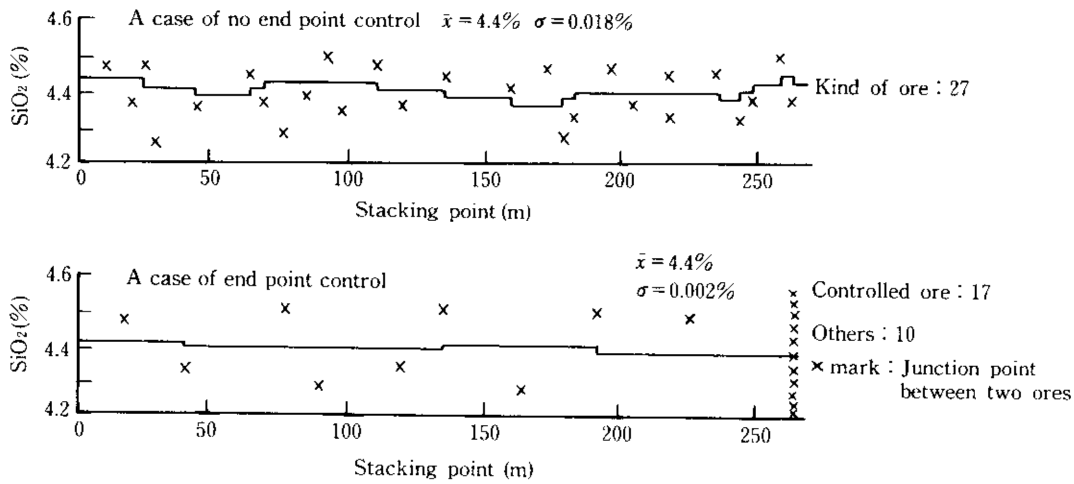


Fig. 5 Improvement of SiO_2 variation by end point stacking control

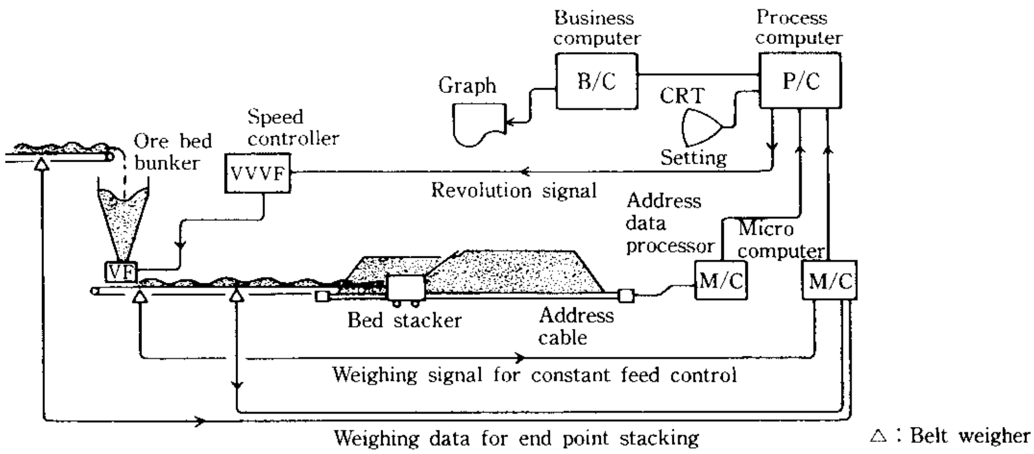


Fig. 6 Ore bed quality controls and monitoring system

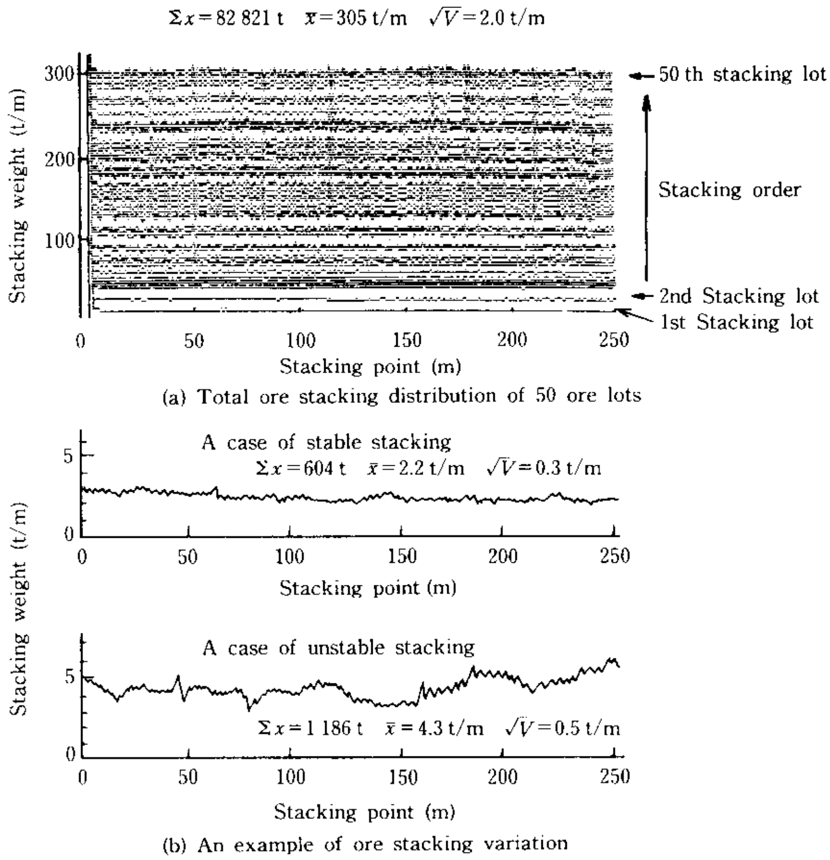


Fig. 7 Bed stacking distribution graphs by bed quality monitoring system

Thirty-five brands of ore were bedded in 50 lots. The reason why the number of lots is larger than the brands of ore is that ore of the same kind is separately bedded at different times. Figure 7(b) shows the longitudinal distribution of stacked weight of a single brand of ore. Some ores show great variations in stacked weight ($\sqrt{V} = 0.5$ t/m), some show small ($\sqrt{V} = 0.3$ t/m). Figure 7(a) shows the stacked weights of these multiple brands of ore in the height direction of the bed. Figure 7(a) is composed of many lateral lines corresponding to the conjunctions of ore lots or brands. Vertical variations of these conjunctions represent variations in stacked weight for each ore lot. In the bed quality control, variations in stacked weights for each brand of ore and for the whole bed are quantitatively monitored using the stacked weight distribution graph shown in Fig. 7 so as to help identify the cause of the variations and take appropriate measures. **Figure 8** shows results of chemical composition calculations made by using the above-mentioned stacked weight information. Varia-

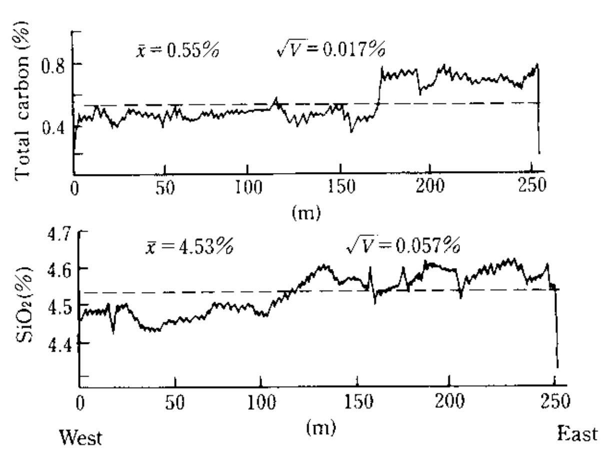


Fig. 8 Distribution of chemical composition along bed stacking direction (35 ores)

tions in the carbon and SiO_2 contents in the bed are grasped and bed quality assurance is quantitatively conducted. The bed quality information is reflected in a sintering operation to enhance sinter quality control.

3.4 Dynamic Charging Control of Blast Furnace Bins

In the case of blast furnace sinter bins, a single unit of self-propelled charging conveyor performs all charging into multiple number of sinter bins. This causes a difference in stock level between some of the bins in the case of a simple sequential charging at fixed time intervals. The pulverization of lump ore during charging into bins increases abruptly when the fall is large. For the prevention of pulverization during charging, therefore, it is useful to eliminate the difference in stock level between all bins, even if the total amount of stock in all bins stays the same.

In view of the foregoing, a dynamic charging control system developed for blast furnace sinter bins. **Figure 9** shows the configuration of this system. The calculation of the amount of bin stock is automatically made by the process computer. A bin with a minimum stock amount is found among bins and the order to travel is given to the electric sequencer for bin charging. The charging time is determined from the charging velocity and discharging velcoity in such a manner that the difference in stock level between the bins can be minimized. **Figure 10** shows an example of advantage of this control. It is apparent from this that variations in stock level among bins decrease greatly in a short time.

3.5 Power Saving Control

The ratio of power cost to the total ore treatment cost of the ore yard is very high. To reduce the unit power consumption, it is necessary to improve the transportation efficiency and prevent idling. This can be achieved by full use of the above-mentioned functions of operation monitoring. To perform thorough power management, it is important to have a quantitative grasp of the actual state of power consumption and apply data thus obtained to process control. A power consumption monitoring system of quick response was developed by

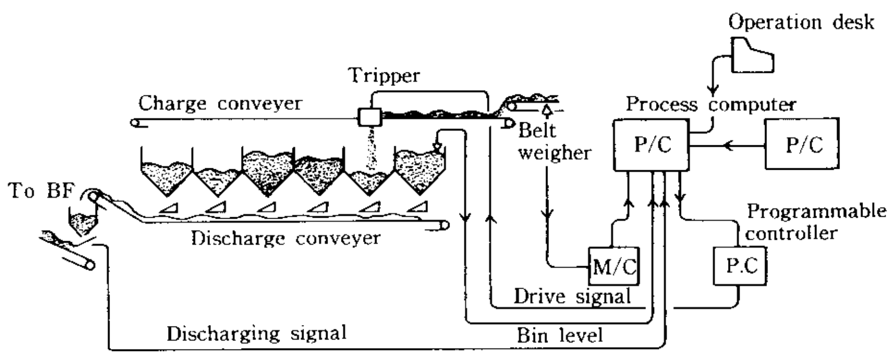


Fig. 9 Dynamic hopper level control system

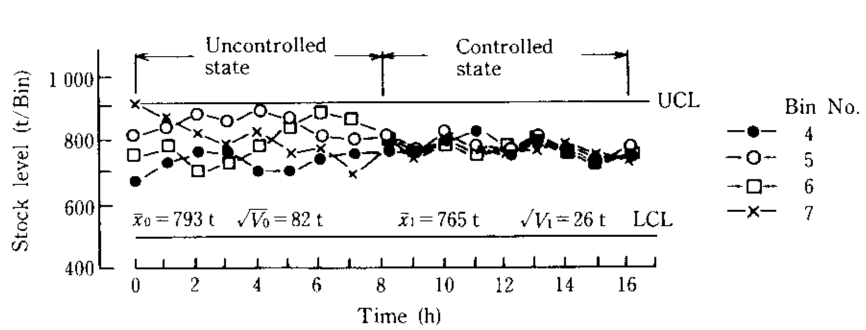


Fig. 10 Effect of dynamic hopper level control on variation between several bins

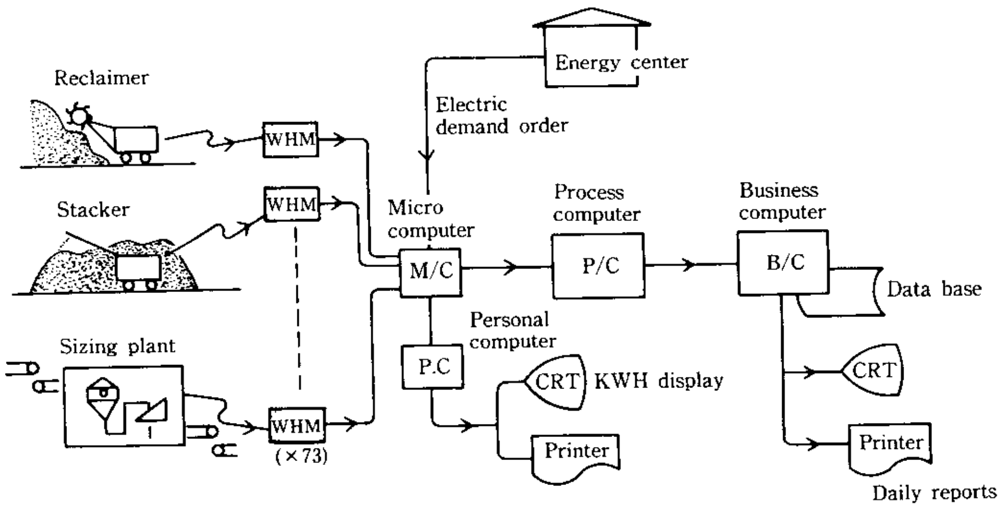


Fig. 11 Electric utility management system

installing some 70 electronic watt-hour meters on key control equipment in the ore yard. All power data gathered are stored in the business computer through the microcomputer and are outputted on the daily control report. **Figure 11** shows the configuration of this system. By using this system, the unit power consumption for each ore transporting machine is examined so as to improve equipment characteristics of both electrical and mechanical systems. In this manner power-saving is pushed forward covering both software and hardware.

In addition, this power consumption monitoring system is connected on-line to the power demand control system of the entire works and the ore yard operation hours are adjusted, as necessary, so as to prevent a works-wide peak consumption of power.

3.6 Unloader Operation Control

The raw materials berth of Mizushima Works is 17 m maximum in water depth and 1.8 km in total length and is equipped with six rope trolley type unloaders (maximum capacity: 1 500 t/h) and four level luffing type unloaders (maximum capacity: 500 t/h). Since the raw material unloading department is the entrance to a coastal steelworks in terms of material handling, an improvement in the operation efficiency in this department results in a decrease not only in the cost of raw material unloading, but also in demurrage, with an increase in dispatch money caused by decreased lay days, thus leading to a reduction in raw material transportation costs.

In recent years, the ship size has become larger with its structure diversified to reduce the marine transportation cost. Against this background, the role of the unloading department has become increasingly important and complex. To cope with this situation, new unloading machines are under development and the capacity of existing unloaders is being increased. The improvement of techniques for operating existing unloaders is also an important task. The unloading operation control system developed this time uses microcomputers to gather automatically detailed information on operation results, which has so far escaped, making possible a high-accuracy operation control based on unloading data obtained from each grabbing operation.

Figure 12 shows the configuration of this system. Various data obtained at the unloader during unloading (grabbed weight, cycle time and unloader position) are digitally displayed real-time on each occasion in the unloader operator cabin. The operator uses these data for his own operation judgment. At the same time, these data are displayed on the operation monitoring CRT in the ground-level control room through an inductive address cable (about 1.2 km long) laid along the travel range of the unloader. The data are used there for operation monitoring. Furthermore, the business computer stores operation data for each ship and unloader for a long time to use them for preparing operation control graphs and other daily operation reports as well as for analyzing operations.

Figure 13 shows an unloading trend graph for operation control prepared using the business computer. This graph shows an example of the work done by one of the six unloaders on the Chishirokawa-Maru loaded with Mt. Newman ore. Figure 13 shows the grabbed weight, cycle time, unloading efficiency and operation hatch number from start to end of operation. The symbols A, B and C in the figure represent different operators. In comparison of the features of these three operators, **Figure 14** shows histograms of the cycle time and grabbed weight. Operator A is stable in both grabbed weight and cycle time and shows the best unloading efficiency among all operators. Operator C shows considerable variations in the grabbed weight although the cycle

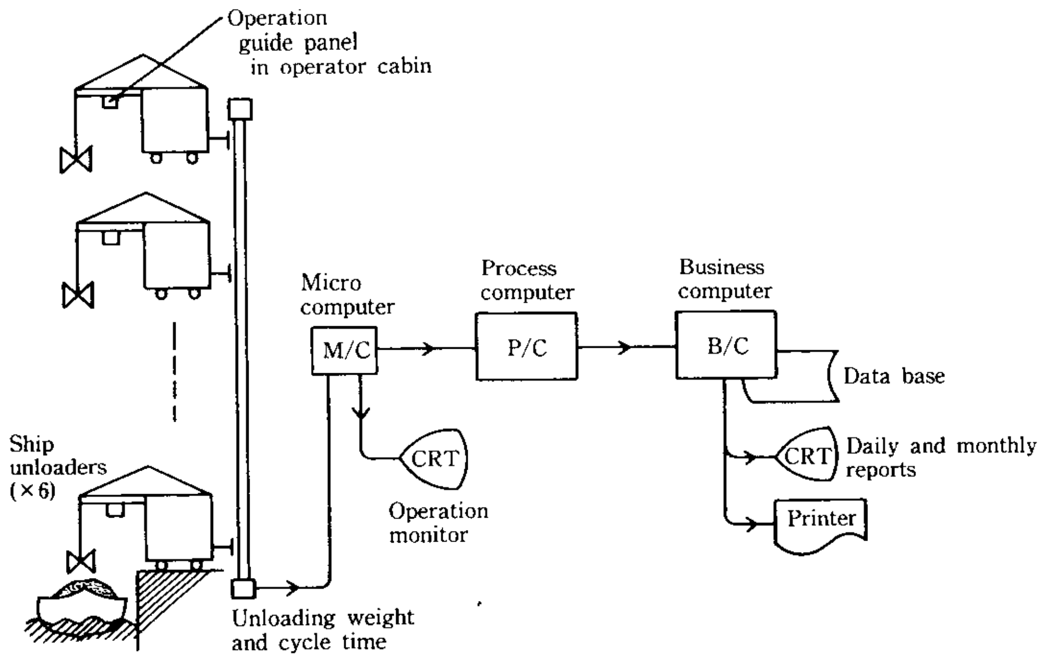


Fig. 12 Ship unloading management system

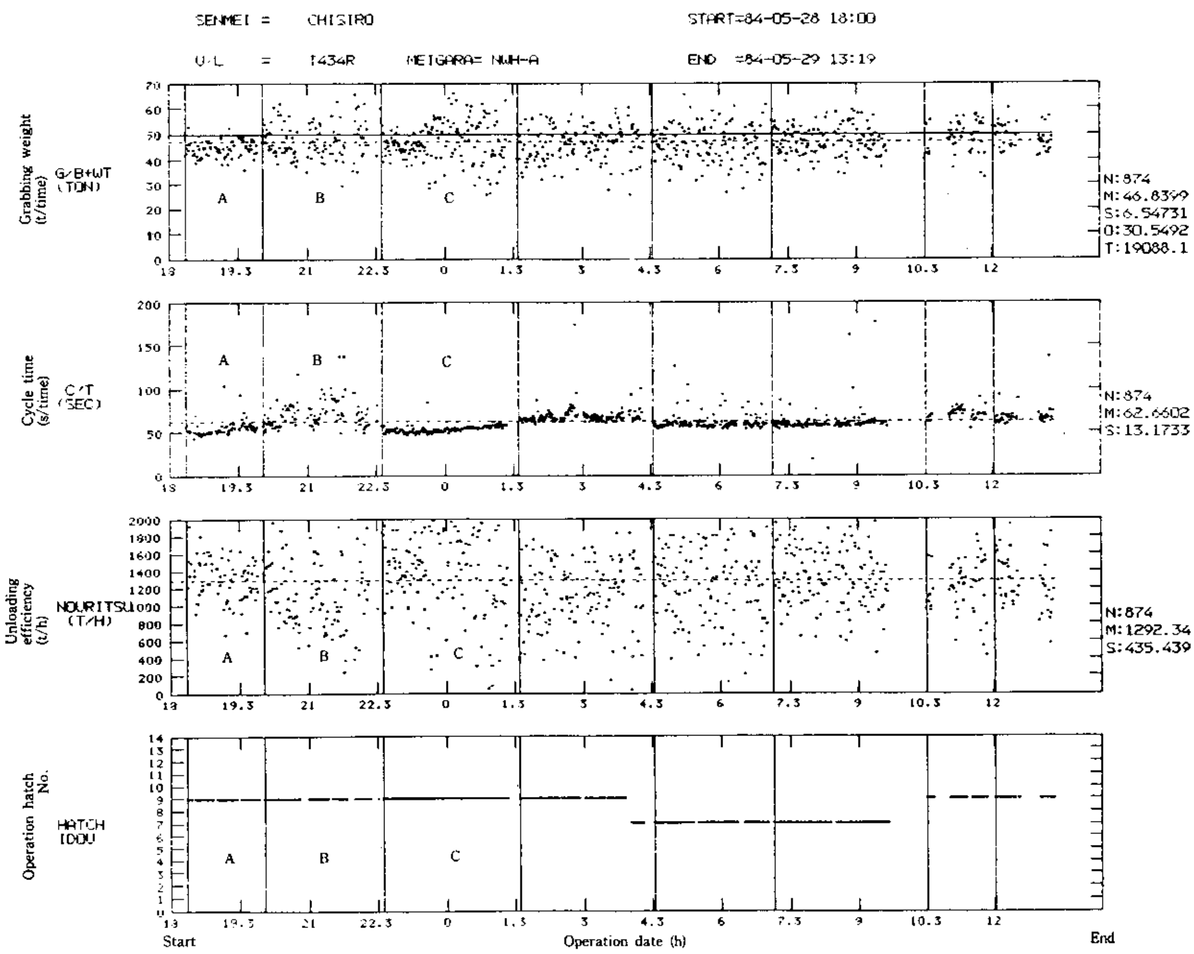


Fig. 13 Ship unloading trend graph of each grabbing data

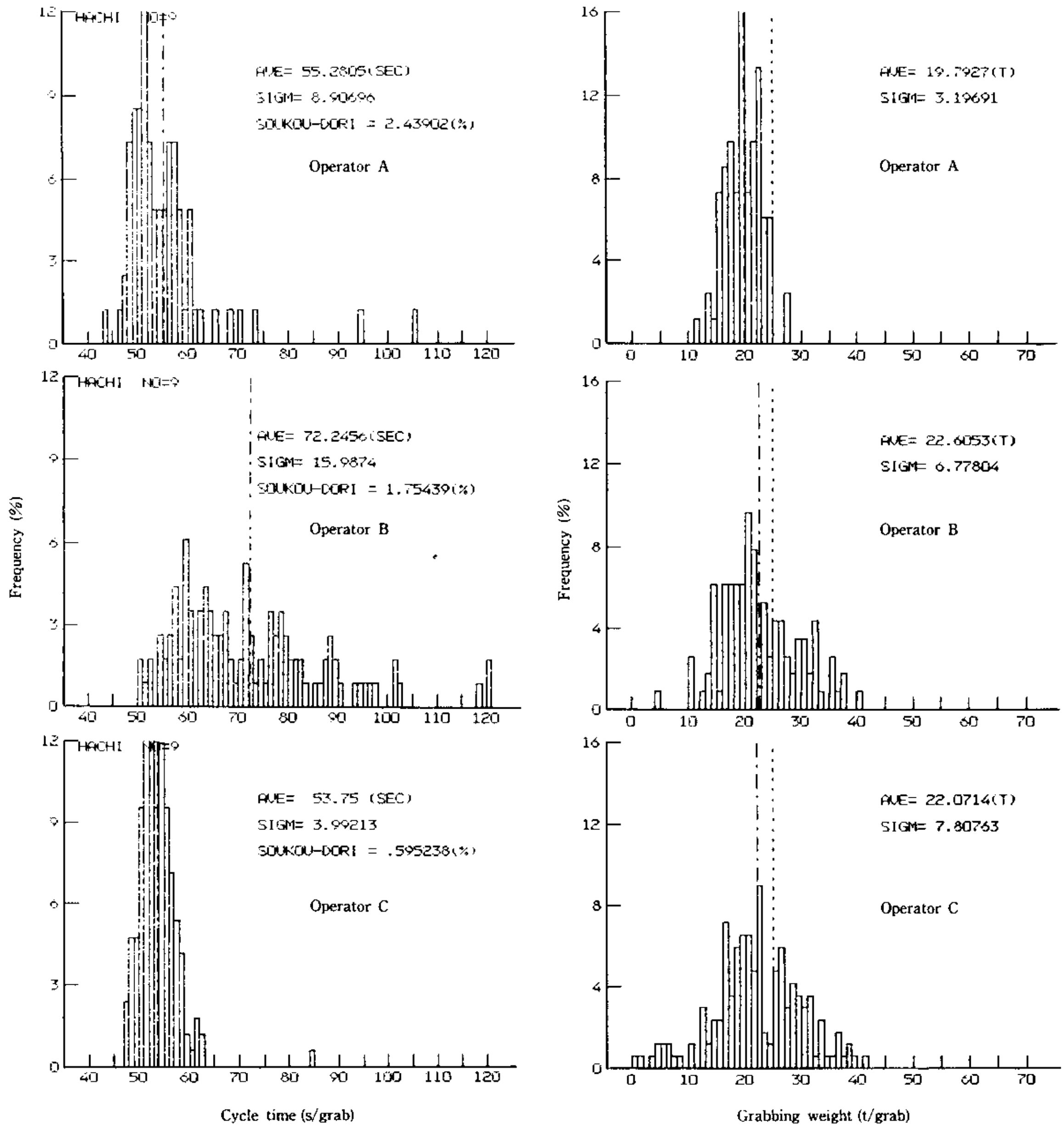


Fig. 14 Comparison of unloader operator's skills

time is short and shows small variations. Therefore, it is necessary for Operator C to try to improve his skill in manipulating the grab bucket. Operator B shows large variations both in cycle time and grabbed weight and is required to improve his skill in manipulating the grab bucket in every respect.

The features of operation skills are quantitatively identified by an effective use of the operation data of each operator. Mutual motivation and effective training among operators are conducted in this manner to improve the unloading efficiency. Furthermore, the effect of the brand of ore handled and the type of ship on the unloading efficiency is quantitatively determined so as to improve the accuracy of the berth planning and the hatch planning.

4 Conclusion

A total ore yard system was completed in the ironmaking department of Mizushima Works as part of the development of a total ironmaking information system. The development of this ore yard system has permitted a centralized control of the physical distribution and quality information of the ore yard process, with marked improvement in process control. Mizushima Works intends to push forward the ore yard operation efficiency by effectively utilizing this system.

The labor and economic environments of the steel industry are expected to become increasingly severe in the future and substantial rationalization is required also in the ore yard department of steelworks. To cope with this situation, it is necessary to make comprehensive improvements in information systems, including the integration, rearrangement and revitalization of hardware. In this ore yard at Mizushima also, automation techniques for stackers, reclaimers, unloaders, etc., will further be developed based on the above-mentioned information and control system to save labor and energy and improve productivity.

The authors would like to express their sincere thanks to all the persons concerned for their excellent cooperation extended in the electrical and instrumentation phases in the construction of this system.

References

1) T. Yamada, M. Saino, S. Nigo, S. Yamana, Y. Senoo S. Moriya, N. Imotani and Y. Segawa: *Kawasaki Steel Giho*, **13**(1981)4, 118–128
2) Y. Segawa, O. Iida, N. Imotani, S. Nigo, H. Obata, S. Taniyoshi: *Kawasaki Steel Giho*, **16**(1984)1, 1–7
3) S. Yamana, S. Nigo, H. Obata: "Quality Control of Raw Material and Fuel," Raw material Session, July, 1981 edited by Union of Japanese Scientists and Engineers
4) S. Yamana, S. Nigo, A. Fukuda, K. Wakai, M. Saino, T. Yamada: *Tetsu-to-Hagané*, **67**(1981)4, S99