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Totalized System for Iron and Steel Analysis at an Integrated Steelworks*


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1 Introduction

In recent years, steel makers have changed their manufacturing techniques to reflect the demand for higher grades of steel and high value added products. This has resulted in analytical methods becoming more diversified and accurate and it is now necessary for large quantities of analytical information to be quickly transmitted to production lines. New techniques are making this possible, through the development and introduction of new equipment, automatic analysis, and better use of computer systems[1,2].

In October 1986 at the Mizushima Works of Kawasaki Steel, the entire analysis system was redesigned when the material flow between steelmaking and hot rolling was synchronized. This analysis system included the pretreatment of analysis samples, actual analysis, measurement and the storage and transmission of analytical information[3].

This report outlines the features of this new system.

2 Basic Concept of Computerization

2.1 Conditions for Computerization

The new computer system at the Mizushima Works is mainly designed for analysis and control of operations. This is because a large number of operations must be simultaneously and frequently analyzed, because reactions in blast furnaces, converters and ladles change in a very short time and the specified tolerance ranges are very narrow. There are also strict limitations on the feed-back time, and the analytical equipment is used intensively. In off-line analysis, however, the effect of computerization and automation has been small because there is a much wider range of analysis which is performed in small quantities with less strict time constraints.

The system was designed to meet the following general requirements:

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(1) Analytical Operations
Measurement frequency and speed during 24-h operation must be very high.
(2) Analysis Techniques
Analytical instruments must be adaptable to the computer system and use techniques capable of coping with on-line analysis.
(3) General-Purpose Adaptability
Common techniques or those capable of being shared must be used so that analytical instruments and labor can be effectively utilized.
(4) Automatic Analysis Management
Sample pretreatment, measurement, and information processing must be automated as much as possible.

2.2 Basic Implementation Concept

Operational efficiency and improved analytical precision were to be achieved through the speed and accuracy of computers. Other benefits are integrated control of analytical information and expanding the scope and speed of operational and quality control. The following points were therefore carefully considered when developing the system.

(1) Equipment and instruments necessary for operation control and analysis must be connected on-line with a computer.
(2) The system must be expandable in order to meet changing requirements. In consideration of system failures and ease of maintenance, the system must be arranged so that functions are not concentrated on only a few instruments. A backup system must also be provided at low cost.
(3) To improve efficiency and reliability, the system must be paperless.
(4) Precision control of analytical instruments, statistical management, receiving and recording of analysis samples and management of daily and monthly reports must be computerized.

Effective utilization of analytical instruments and labor and the reduced cost of analysis are the principal merits of the computer system. Automatic analysis is more efficient and rapid than the former labor-intensive system, but it must suit the characteristics of the samples and their means of analysis. Thus the sample preparation apparatus, analytical instruments the transfer apparatus connecting them was also automated. It is also possible to operate the apparatus and instruments separately.

3 Outline of Analytical Computer System

A hierarchical structure in which the computer management functions and control of the instruments are separated in consideration of reducing problems and ease of maintenance was adopted for the analytical computer system, as shown in **Fig. 1**. The analytical process computer automatically collects information from the host system, slave system and various terminal devices, transmits such information, and calculates various constants for the control of analytical precision of analytical instruments and for correlation and regression.

Analytical computers at a lower level in the hierarchy control the analytical instruments, calculate the analysis values, and send and receive information to and from the analytical process computer.

Automatic analysis equipment is composed of sample pretreatment apparatus, analytical instruments, and sample transfer apparatus. Sequence controllers are provided for controlling the various apparatus and instruments to ensure equipment durability and to facilitate the control of constants.

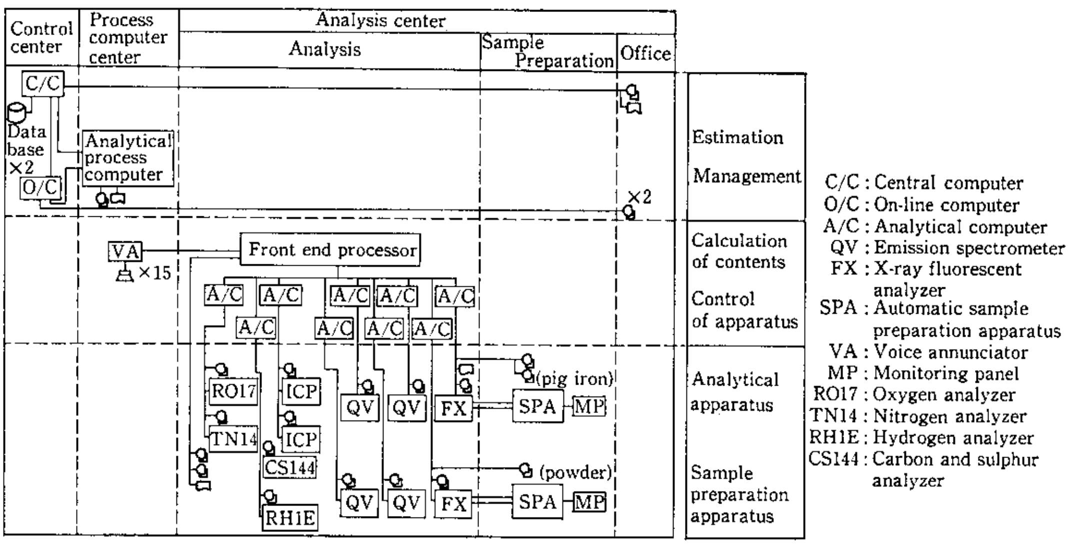

Fig. 1 Hierarchical structure of analytical computer system

Table 1 Specifications of analytical instrument

Item	Specification
Emission spectrometer	
Type	Vacuum quantometer GVM-100, GVM-1000 and GVM1016
Range of wavelengths	165.0 nm~450 nm
Excitation sources	HPSG-400 and SD-400
Analytical elements	21~32
X-ray fluorescent analyzer	
Type	Vacuum spectrometer VXQ-150 and VXQ-150A
Excitation sources	Rh target (3 kW max)
Analytical elements	22 and scanning 10 elements
ICP emission spectrometer	
Type	Spectrometer JY48 and 975 ATOMCOMP
Range of wavelengths	170.0 nm~500.0 nm
Radio frequency output	1.3 kW
Analytical elements	24~32
Carbon, sulphur analyzer	Type CS144, H.F combution-infra red method
Oxygen analyzer	Type RO17, Impulse fusion-infra red method
Nitrogen analyzer	Type TC136, Impulse fusion-thermo-conductivity method
Hydrogen analyzer	Type RH1E, Impulse fusion-thermo-conductivity method

3.1 Analytical Instruments

The main specifications of the analytical instruments are given in **Table 1**. Four emission spectrometers, an X-ray fluorescent analyzer, an oxygen analyzer, a nitrogen analyzer and a hydrogen analyzer were installed to analyze pig iron and molten steel samples. An X-ray fluorescent analyzer was installed for powdered samples of sinter, blast-furnace slag, converter slag, etc., and ICP emission spectrometers and a carbon and sulphur analyzer were installed to check and analyze raw materials and products.

The pulse height distribution analysis (PDA) method was adopted for all the emission spectrometers to permit the instantaneous analysis of soluble Al, which is an important factor in ladle metallurgy and improves analytical precision.

3.2 Configuration and Features of Hardware

3.2.1 Equipment

The configuration of the analysis system at the Mizushima Works is shown in **Fig.2**.

The analytical process computer was installed in the steelmaking process computer room for easier communication and maintenance. This is about 2 km from the input/output control computer (front end processor) installed in the analysis center, so they are connected by optical fibers in consideration of the amount of information and the need for reliability. Each of the emission spectrometers and X-ray fluorescent analyzers, from which a large amount of information is obtained, is connected to one analytical computer (1 : 1), while the steel gas (oxygen, nitrogen and hydrogen) analyzers, carbon and sulphur analyzer and ICP emission spectrometers are connected to analytical computers at a ratio of 2 : 1 to permit simultaneous analysis management of each pair.

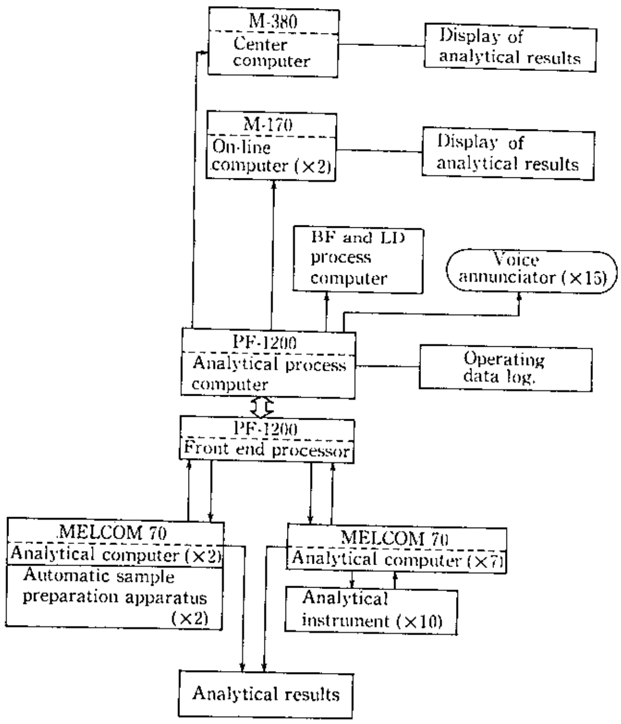

Fig. 2 Function of analytical computer system

All interfaces with operators are through CRT display devices: 20-in. CRT screens were adopted for the emission spectrometers, in which the amount of information and the number of analytical elements are large and where the operators must stand while working to improve visibility. 14-inch CRT screens are used for other analytical instruments at which operators sit while working. The central computer and on-line computers are used as data bases for the storage of analytical results, and from which information can be retrieved if necessary. The system is paperless, and announcements are made in each production area using voice annunciators.

Features of the system configuration are listed below.

(1) The front end processor installed in the analysis center has the same hardware configuration as the analytical process computer. When the level of the analytical process computer is raised in the future, the analytical process computer can be converted into another front end processor so as to provide a

duplex system.

(2) Optical transmission is adopted for communications between the analytical process computer and the front end processor because of its high transmission speed (13.4 MBPS) and to ensure easy maintenance. Transmission is in a total duplex communication system and information can be transmitted in the reverse direction if a transmission cable is broken.
(3) Three ports were installed for the connection between the front end processor and the analytical computers, and the risk of failure was reduced by allocating four analytical instruments to each port.
(4) Only CRT screens are used as terminal devices for the analytical process computers and analytical computers, and hard copies are only obtained when records are needed.
(5) The automatic analysis system uses standardized X-ray fluorescent analyzers as analytical instruments, and sensors for checking the thickness and surface condition of samples were installed to exclude poor samples. Furthermore, an operation monitoring panel was provided in order to see the operating condition of each device and the progress of sample preparation.

3.2.2 Features of CRT operation

The first thing to consider in adopting full-scale CRT operation was the reliability of CRT display devices. The man-machine information interface is concentrated on CRT display devices, so trouble with CRT display devices will paralyze the system. This problem can be solved by multiplexing CRT display devices and controllers. However, simple multiplexing increases costs and reduces the cost-saving effect of the whole system. For this reason, multiplexing was used only after careful consideration of the configuration. For example, all CRT display device controllers of the analytical computer share the same hardware specifications to facilitate interchanging and maintenance.

The next thing to consider was the format of the CRT screens. Various kinds of information, such as operation instructions, information on blowing, the history of samples to be analyzed and analytical results, are needed for operation control analysis. However, all of this information is not usualy required at the same time, so simply combining some pieces of information suited to the sample to be analyzed is sufficient. Therefore, a large number of screen patterns suited to the appropriate operations were made and suitable screen patterns are selected by the menu method as required. To permit quick input from a keyboard and to prevent input errors, function keys are frequently used so as to minimize the number of touch operations and, at the same time, processing by inputting numbers through a ten-key pad is possible.

3.3 Software Features

The processing functions of this system are basically divided into information gathering by the analytical process computer and analysis operation functions by the analytical computers.

3.3.1 Information gathering functions

Processing functions related to analysis are classified as shown in **Table 2**. They include operation guidance, analytical precision control, data maintenance, and technical analysis. In this respect, the analytical computer supports the oerators through the graphic display of plant operation information, operating conditions, etc., thus making it easy for operators to understand the status of operations. Furthermore, it performs crosschecks among analytical instruments, thereby improving reliability. These functions are detailed as follows.

(1) Voice output of analytical results is the most effective method. Unlike visual devices such as electric bulletin boards, analytical values are announced throughout the production area and female voices are used to attract special attention.
(2) Control of analytical values is made possible by studying the precision and accuracy of analytical instruments. $\bar{X}$-R control is used to find variations in analytical samples every two hours, $\bar{\bar{X}}$-R control is used to find daily variations in analysis samples, and accuracy control is conducted to find the correlation between the analytical values obtained by instruments and values obtained by chemical analysis. This data is processed and graphically displayed on the CRT screens. Examples are shown in **Photos 1** and **2**.
(3) Object table files and history table files are used for storing analytical values. The former files are used when operation is continuous as with blast furnaces, sintering plants, etc. and 20 to 50 cases are stored in a file for each plant in a time series manner. The latter are used when operation is composed of a series of continual steps in a batch manner as with the process from converter refining through ladle

Table 2 Function of data management

Item	Function
Input/output	MODEM, EF T/W, voice annunciator
Control of operation commands	L/D, EF, C/C
Control of analytical results	$\bar{X}$-R chart, $\bar{\bar{X}}$-R chart, analytical accuracy
Calculation	Analytical precision, statistical calculation
File	
Sum total	

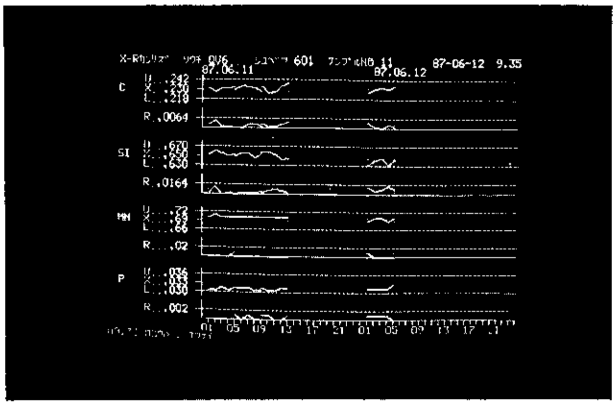

Photo 1 Example of CRT display ($\bar{X}$-R chart)

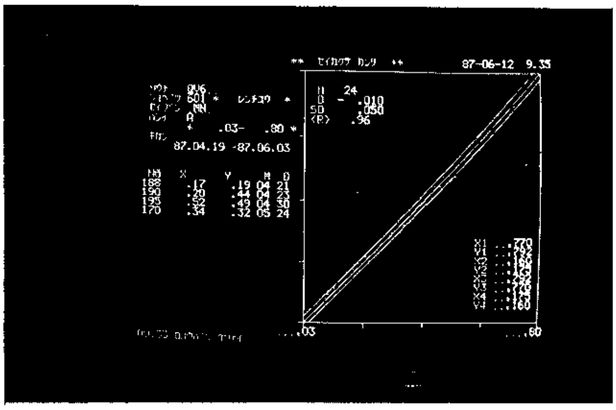

Photo 2 Example of CRT display (control chart of accuracy)

metallurgy to continuous casting. Data are filed for each furnace number and heat number in a time series manner. According to instructions from the analytical computers, data files are sent to the analytical computers and are displayed on CRT screens in a time series manner.

(4) Another feature of the automatic analysis system is that an acceptance or rejection judgment is formed as soon as the analytical values are calculated. Analytical values are automatically transmitted to the host system when they are judged to be within set allowable ranges. If there are problems with analitical instruments, alarm code numbers are displayed on the CRT screens to facilitate maintenance.

3.3.2 Operation analysis functions

Processing functions are given in **Table 3**. They include calculation of analytical values, analytical information and automatic analysis. Preparation of calibration curves, calculation of correction factors of coexisting elements, etc., can be conducted in a paperless manner in addition to the analysis of operations. Furthermore, it is possible to select analysis conditions, calibration curves, the number of analytical elements, number of figures of analytical values, etc., thereby speeding up operations and, at the same time, decreasing the burden on operators.

Table 3 Function of analysis operation

Item	Function
Analytical instrument	Start, stop, reset, recycle, maintenance
Automatic analysis	Sample set, polishing, grinding, sample transfer, measurement of X-ray intensity
Contents calculation	P.D.A., correction of coexistent elements, contents calculation
Analytical information	Analytical condition, constant of calibration curve and correlation, channel information, format of data transfer
Input/output	Analytical P/C, analytical instrument, CRT, printer

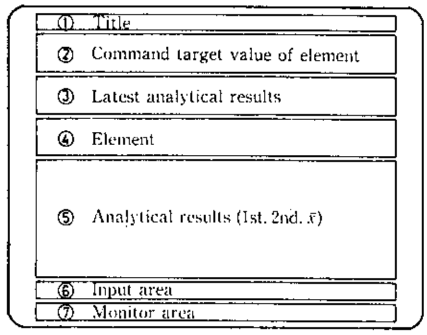

Fig. 3 Design of CRT display

(1) Composition of CRT Screens

CRT screens are broadly divided into "analysis screens" used during analysis, "analytical information screens" for entering and updating analysis conditions, constants of calibration curves, correction factors, etc., and "maintenance screens" for displaying the condition, use condition, etc. of analytical instruments. A menu system was adopted so that operators can easily select the appropriate screens. By way of example, **Fig. 3** shows a history table screen used for analyzing molten steel samples in converter refining, ladle metallurgy, continuous casting, etc., which is the most frequently used of the screens. The screen displays, from top to bottom, ① heading (name of analytical object), ② operation instructions for the analysis sample and target values of steel components, ③ latest analytical values for the analysis sample (in terms of the same furnace number and heat number), ④ name of analytical element, ⑤ analytical values (single analysis, double analysis and mean), ⑥ input area, and ⑦ monitor area (comments or messages).

(2) Operation of CRT Display Devices

Because analysis is conducted on-line, the highest priority was given to speed and the prevention of entry errors, so a standardized operation method was adopted. When a classification code is entered on the keyboard and the return key is depressed, input items are displayed in up to seven colors. Analysis begins when a furnace number, heat number, blast furnace number, sample number, etc., are entered on the ten-key pad. All analytical instruments and analytical objects can be handled by keyboard input.

3.4 Outline of Automatic Analysis

Automatic analysis was selected for samples for which rapid analysis is required, where the number of analysis requests is very large (more than 100 requests a day), or where pretreatment is very complex and takes a long time.

3.4.1 Powder sample analyzing system

The equipment of this automatic analysis system is illustrated in **Fig. 4**. Specifications of the equipment are outlined as follows.

(1) Sample Preparation Apparatus

Treatment time: 6 min

Crushing method: Rough crushing–Pulverizing by a hydraulic crusher–Vibrating disk mill

Collecting method: Separating the samples from the air by a minicyclone

Press pressure: 50 t (30 s)

Control: Sequence controller

(2) Sample Transfer Apparatus

Transfer speed: 0.3 m/s

Transfer method: Belt conveyor

Waiting samples: 4 samples maximum (1 sample on the side of each of 3 crushers and 1 sample on the side of the press)

(3) X-ray Fluorescent Analyzer

Integral action time: 20 s

X-ray tube: Rh target, output 40 kV–70 mA

Spectrometer: 22 fixed elements, one scanner (for heavy elements)

Sample collection: Sliding the sample on a miniature belt conveyor

In this system, one sample can be treated in about 6 min if one crusher line only is operated. However, samples can also be continuously analyzed at a frequency of 3 min per sample because the analyzer and the sample preparation apparatus can operate at the same time on each of three crusher lines.

3.4.2 Pig iron analyzing system

The equipment of this system is schematically shown in **Fig. 5**. This system comprises a grinder, sample preparation apparatus, X-ray fluorescent analyzer, and computer. Main specifications of the system are described below.

(1) Grinder

Grindstone: Cylindrical grinder (1 500 rpm under no-load)

Electric motor: 3-kW motor for grinder, DC servo-motor (2 000 pulse/revolution) for control

Cooling method: AIRCOLDER (−20°C)

Sensor for detecting poor samples: Light reflecting type

Sample turning: Robot arm

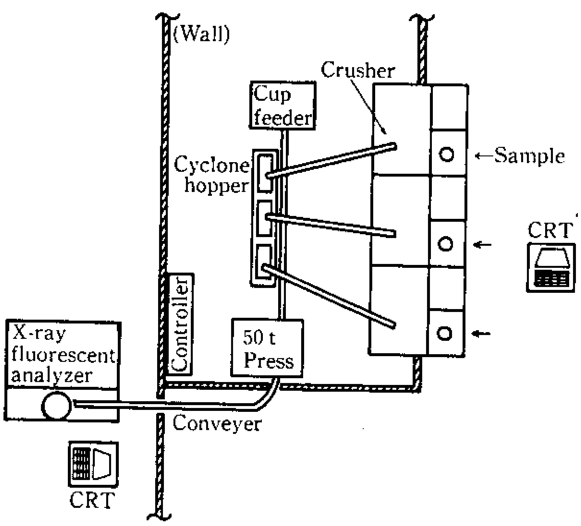

Fig. 4 Schematic diagram of the full automatic analysis system for powdered sample

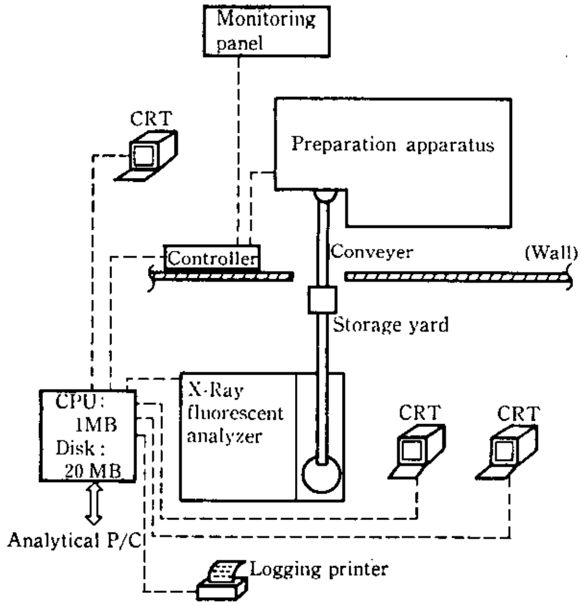

Fig. 5 Schematic diagram of the full automatic analysis system for pig iron

(2) Sample Preparation Apparatus
Transfer speed: 0.25 m/s
Transfer method: Belt conveyor (120°C heat resistant)

(3) X-ray Fluorescent Analyzer
Integral action time: 30 s
X-ray tube: Rh target, output 40 kV-70 mA
Spectrometer: 23 fixed elements, one scanner (for heavy elements)
Sample collection: Sliding the sample on a miniature belt conveyor

In this system, one sample can be treated in about 3 min. However, samples can be analyzed at a frequency of 2 min per sample because the analyzer and the grinder can operate in parallel.

4 Conclusions

The automatic analysis system at Kawasaki Steel's Mizushima Works was partially brought into operation in January 1984 and came fully onstream in October 1986 with the start-up of a synchronized operation system between steelmaking and hot rolling. An automatic powder sample analyzing system and automatic pig iron analyzing system were brought into operation in March 1984 and in April 1986, respectively, and have since been operating smoothly after some modifications and improvements.

The following effects have been obtained by the application of this system:

(1) Shorter analysis time and improved ease of operation by full-scale CRT operation.
(2) Reduction in the number of operations, such as recording and reporting, improved reliability and faster communication by a paperless system.
(3) Reduction in required analysis time as well as the elimination of variations in required time and in analytical precision.
(4) Reduction in the number of analysis personnel.

This analysis system has greatly contributed to enhancing the operation control system and quality control system for iron and steel production.

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References

1) I. Taguchi, A. Onoda, and R. Matsumoto: *Tetsu-to-Hagané*, **60**(1974)14, 2035
2) J. Ono, I. Fukui, and N. Imamura: *Shimadzu Review*, **35**(1978)2, 15
3) T. Nakanishi, K. Ohsugi, N. Itakura, Y. Nakagawa, T. Taniri, and T. Ueda: *Tetsu-to-Hagané*, **70**(1984)12, S1078