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COMPUTER CONTROL SYSTEM FOR LD CONVERTER

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I. INTRODUCTION

Lintz-Donawitz process (LD process) (basic oxygen steel making process) was practised on a commercial basis in Austria in around 1952.

In Japan, the first LD converter was fired for the first time in 1957. Since then, LD process has made a startling progress, totally replacing the conventional open-hearth process because of excellent productivity, economy and proven product quality. Now LD process is the first principle of iron and steel making in Japan.

LD converter requires as short a tap to tap time as some 40 min. and as short a blowing time as something like 20 min., standing for its high productivity.

As a consequence, it is of great importance to precisely control blowing processes by always directing the chemical composition, temperature and quantity of heat, especially at the end of blowing, toward respective command values. There are many factors affecting the chemical composition and temperature of heat at the final stage of blowing process, and also they are closely related to each other. These factors are therefore difficult to account independent of each other. It is also a ruling factor in the increase of production efficiency to grasp these influencing factors upon which to form a sweeping judgement in such a short blowing time as noted above.

The homogenization of product quality through the stabilization of working operations is of controlling importance in the process management. For this purpose, the individual errors due to workers should be minimized. In order to fulfil these process requirements, the advent of a control system having high data processing capacity has been longed for. Consequently, the application of computer to the system control emerges out. The computer which was tried for the first time in the United States in 1960 has made a rapid progress, and has become a vital element of LD converter control system in recent years.

We delivered the first example of LD converter computer control system to Tobata Plant of Yawata Iron and Steel (now called Nippon Steel Corporation into which Yawata Iron and Steel and Fuji Iron and Steel were merged) in 1964. Since then, we have delivered six sets of LD converter computer control system. Outline here is our LD converter computer control system which we hope would provide something of a basis for the LD converter process.

II. OUTLINE OF THE PROCESS

LD converter is a large crucible type rotary furnace having a heat capacity of 50 tons to 300 tons.

It is run in a batch form as illustrated in *Fig. 1*. The furnace is charged with scrap and hot metal as primary materials and with limestone, iron ore and fluorspar as secondary materials. The lance is then inserted into the furnace to blow oxygen onto the molten metal surface. By this oxygen blowing, silicon and phosphorus are oxidized and form slag together with limestone. Carbon inside the hot metal becomes for the most part carbon monoxide gas, the remaining part assuming carbon dioxide gas which is to be purged out of the furnace.

The hot metal and slag are violently stirred by oxygen jet blow and carbon monoxide gas produced incidentally, whereby chemical reaction and refining are spurred. Upon completion of the blowing process, sampling is carried out to measure hot metal temperature as well as to assay chemical composition. If in this case the hot metal has attained a specified temperature and a required proportion of elements, tapping is conducted while fluxes and alloying elements are being dosed in order to adjust the chemical composition.

Hot metal weighing *Scrap weighing*	*Hot metal temp. measurement*	*Scrop charging* *Hot metal charging*	*Blowing*	*Steel temp. measurement*	*Ladle addition etc.*	*Tapping*	*Teeming*	*Stripping*

Fig. 1 Sequence of LD converter process

If, on the other hand, the heat fails to meet the control command, the re-blowing and cooling are required.

These extra jobs largely mar the converter efficiency.

The hot metal is then fetched by a teeming ladle to the teeming platform where it is poured into in-got cases.

The converter process is a kind of batch process, and requires much labor characteristically.

III. CONFIGURATION OF COMPUTER CONTROL SYSTEM

The converter computer control system is usually composed of :

(1) Central processing unit (CPU) and its I/O units ;
(2) Process real-time I/O controller (RTC) ;
(3) Main pulpit data input panel, main pulpit display panel, control panel ;
(4) Relaying equipment ;
(5) Printers for printing out log sheets ;
(6) Furnace instruments ; and,
(7) Power unit for computer

An example of the system configuration is shown in *Table 1*. *Fig. 2* is an example of the system diagram.

In the scheme of its process, the converter is much related to manual work and operator guide system. Namely, the data input and display panels play an important part in the communication between operator and control system. Since the furnace operator transacts with the control system through the medium of the data set panel, data display panel and control panel, the system arrangement should be so designed as not to arrow even a bit of error in between.

Table 1 An example of constituent equipments for computer control system

Equipment	Installation
Central processing unit (CPU)	Computer room
Universal I/O writer	Computer room
Paper tape reader	Computer room
Paper tape puncher	Computer room
RTC	Computer room
Console	Computer room
Air conditioner	Computer room
Output typewriter	Furnace control room
Data input panel	Furnace control room
Display panel	Furnace control room
Relay box	Furnace control room
Display panel	Charging aisle
Immersion pyrometer panel	Charging aisle
Control panel	Furnace aisle
Display panel	Teeming aisle
Display and control panel	Hot metal control cabin
Display panel	Scrap yard room
Control panel	Scrap yard
Power supply	Supply source room
Distribution box	Supply source room

In the converter process, it is often the case that the data requiring manual setting, including those for back-up of the automatic input data, amounts to as many as 100 items. Also, individual data are widely spread in numerical ranges, and some include symbols and characters.

The system should be least susceptible to admit

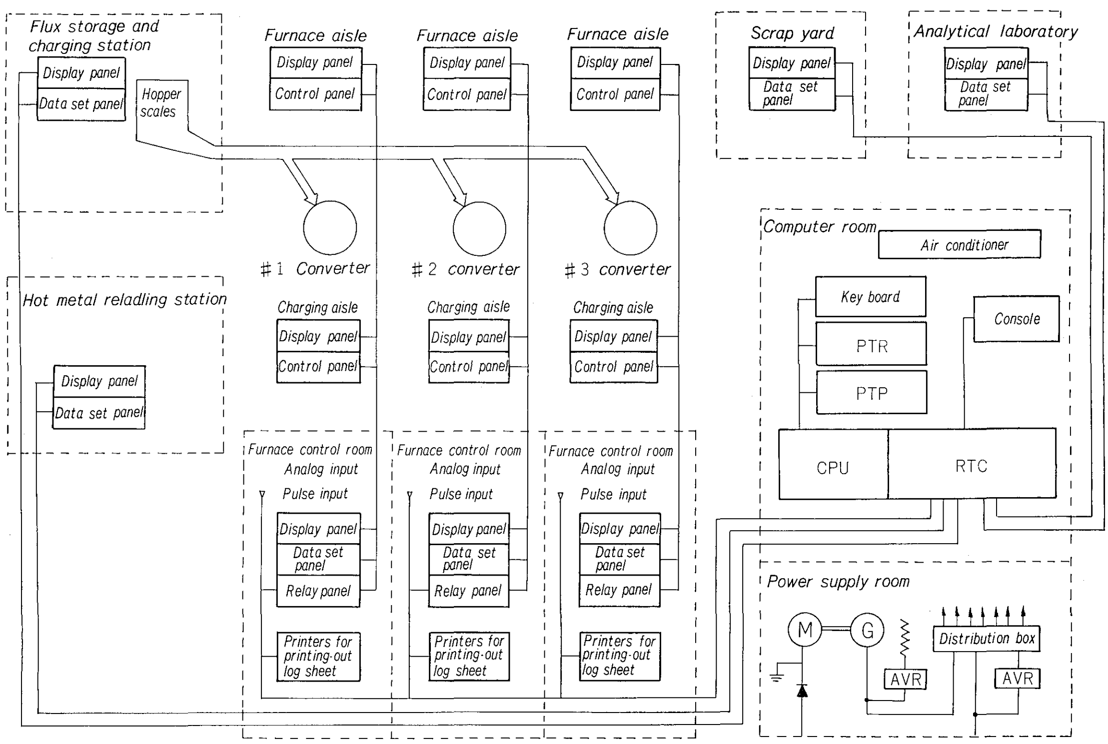

Fig. 2 Skeleton diagram of computer control system

error or omission in setting these data. Not only this, but also the system must be designed to meet all other various requirements including cost and space limitations and operation reliability.

The following gives an explanation on one of our preferred embodiments of the LD converter computer control system.

In this example, the so-called selective setting system is employed. In the first step, judgement is made as to what is selected by the pushbutton control. Along with this, the position of the decimal point is indicated in the numerical setting section in one-to-one correspondence.

In the second step, the timing of the setting is checked depending on its size and importance; namely, in case abnormalities are noticed, alarming is to be effected.

Also, input data can be ascertained whenever required, not to speak of the data at time of setting.

In addition, the setting completion ascertainment signal is given at this time; so that it can be evidenced at a glance to what data the setting has been carried out as to a given heat. Since the data covering two to three charges may have to be set simultaneously at a certain time, they are assorted by heat numbers, and can be set with reference to the heat numbers indicated by automatic digital control.

IV. FUNCTIONS OF COMPUTER CONTROL SYSTEM

Object of the computer control system in the converter process is to save labour, improve working efficiency and quality of product, and above all to increase productivity.

First of all, "to obtain optimal composition and temperature of heat at the end of blowing process" is a matter of primary concern.

In general, the functions of the control system are as follows, though they largely depends on the conditions of the installation and operation.

(1) End-point control (chemical composition and temperature)
(2) Ladle addition control (ferroalloys and coolant)
(3) Sequence control (oxygen flow rate, lance position, flux charging, etc.)
(4) Logging (operation schedule, log sheet, etc.)

In recent years, the LD converter computer control system is often combined with a communication system connected to the associated processes (blast furnace, continuous casting, etc.) or computers of precedence.

In many cases, the end-point control is carried out using a mathematical model. Namely, the working instructions and automatic setting are made according to the results obtained from the model.

The intra-ladle additive control performs calculations of ferroalloys and coolant to direct the succeeding processes or automatic weighing and charging of such additives.

In the sequence control, the control of oxygen flow rate, lance position and weighing and charging of fluxes is carried out, along with notifying the computer of the timing with which the transaction of information for data logging is executed.

The purpose of the logging function lies in the saving of labor by full automation of data collection work as well as in the improvement in the accuracy and reliability of the collected data.

The end-point control and ladle addition control cooperate to increase the level of working efficiency, and the sequence control and logging function to reduce man-hour and standardize operational routine.

V. OPERATION SEQUENCE PROGRAM

The converter sequence program involves a good number of manual operations, and assumes, therefore, a set of programs to be taken up in order of priority.

But, they cannot always follow a fixed sequence; in some cases, programs may be omitted, and in some specific circumstances, the sequence may be indispensable to the progress of succeeding processes.

These programs are all executed by the data stored in common on the magnetic drum, and are interlocked, wherever required, to each other.

As regards the data, the checking is carried out mainly as to size and partly as to the timing of sampling with respect to the sequence. The defective data are blanked off or substituted by calculated values, the values of preceding charge or by the mean values obtained from several precedent charges as occasion demands.

With reference to them, we have developed the following software for the standard system. This software allows easy alteration of those parts at which the operator directly gets in touch with the computer control system (i.e., I/O units); of those connections which provides a route between the mathematical model programs and those parts of the control system which rule the sequence control; and of the interlocking system for sequence programs.

(1) Group control interruption processing program system required to process, by a single computer, a system in which there are n sets of processes having the same functions
(2) Data reading and recognizing subroutine relating to data input panel
(3) ON/OFF indication subroutine
(4) Numeral indication subroutine
(5) Binary coded decimal input/intrinsic decimal input read-in subroutine
(6) Subroutine to make decision as to whether the programs be interrupted (This is applied to the mathematical model programs.)
(7) Logging program (Logging Format selected arbitrarily)
(8) Sequence check subroutine system to check if the

sequence programs are completed or not; the patterns of the program states can be given in a required form of table.

The following gives an outline of one of the sequence programs practised with us.

In this system, the process schedule worker sets a schedule for several heats beforehand. When the blowing work for the last heat is commenced, the blowing worker depresses the heat calculation start pushbutton switch. Thus, the required quantity of the heat is indicated at the furnace control room and the hot metal re-ladling station. In the hot metal re-ladling station, the hot metal is poured into the ladle according to the aforesaid indication, along with ladle analysis and temperature measurement.

In the furnace control room, the flux calculation start pushbutton switch is depressed by the blowing worker around the time when the tapping of fore-heat is set about. With this, the amount of fluxes required is calculated from various data including the scrap quantity, heat quantity, chemical composition of heat, temperature, enp-point temperature and steel grade, and is then indicated at the furnace control room.

The charging of the primary materials is timed by the blowing worker by means of a pushbutton switch at the furnace control room. At the end of hot metal charging, the level of the molten metal inside the furnace is estimated by calculation, and the lance height evaluated thereby is indicated at the furnace control room. Successively, the blowing is started; when the ignition phenomenon is noticed, the blowing worker depresses the ignition pushbutton. By this, the quantity of oxygen required is indicated at the furnace control room with that portion of oxygen which is consumed until the success of ignition being compensated. In time with this, the schedule covering processes up to two heats in precedence is printed out at the typewriter room. The flow rate and pressure of oxygen during blowing work are measured and read out; when the integrated amount of oxygen nears a calculated value, a bell sounds, annunciating the end of blowing to the blowing worker. After completion of the blowing work, the furnace is tilted to carry out end-point temperature measurement and sampling for chemical assay. The temperature is automatically read into the computer through an immersion type thermocouple, and also is indicated on the display board outside the furnace control room, along with necessary manipulated variables with respect to command temperature if required. The end-point chemical composition is analyzed by Quantometer, and the results are sent to the process schedule worker. When the results are input by the process schedule worker, they are collated with the chemical composition of the steel of required grade. The instruction for re-blowing is then given if required. In addition, the indication of the required amounts of ladle additives is carried out. In case where the re-blowing is called for, the calculated re-blowing time can be given by the depression of the re-blowing time calculation start pushbutton switch. In the teeming aisle, the charging of alloying elements is carried out according to the indication of the required amounts of ladle additives on the teeming aisle display panel, and the tapping start and end pushbutton switches are worked.

The operation sequence program for the control system is classified into the following three categories for the sake of convenience.

(1) Operations to be carried out in common to No. 1 and No. 2 furnaces for several successive heats
(2) Operations to be carried out for each heat
(3) Operations to be carried out once every day or more less frequently

1) Operations to be carried out in common to No. 1 and No. 2 furnaces for several successive heats:

These operations are carried out mainly on the common data input panel located at the process schedule worker room. The setting items are the data, shift, crew, crew chief, reference heat code for several heats, command value of good ingot amount, amounts of scraps by brands, etc. These are set at a lump.

2) Operations to be carried out for each heat:

These operations are subclassified into the following three groups.

(1) Operations to be carried out mainly on the hot metal re-ladling station display panel and hot metal temperature controlling display panel:

On the former panel, the hot metal weight (net and gross weights) is read in, and if there is no indication of the required hot metal weight (calculated value), the furnace control room is called to carry out calculation. On the latter panel, the operation and measurement results incidental to the hot metal temperature measurement are indicated.

(2) Operations to be carried out primarily on the furnace control room data input panel, hot metal temperature control panel and teeming aisle control panel:

The setting of the end-point temperature, calculation of hot metal amount, calculation of fluxes, examination of end-point chemical composition and adjustment calculation, start-up of re-blowing time calculation and the setting of abnormal heat are conducted on the furnace control room data input panel. The results are indicated on the respective display panels (display panels inside and outside the furnace control room, hot metal re-ladling station controlling display panel, teeming aisle display panel).

The timing for the start and stop of the primary material charging and for the ignition is accomplished by the pushbutton switches inside the furnace control room; as regards the ignition, the corrected amount of oxygen in which oxygen required for ignition is taken into account is indicated on the furnace control room display panel. In addition, in case of the hot metal temperature measurement, the results of measurement and their adequacy, and adjustment instructions, when the temperature out of target, are given on the display panels inside and outside the furnace control room.

On the teeming aisle control panel, the timing for the start-up and end of tapping is set, and updating or clearing of various data consequent upon thereto is carried out after each heat cycle.

(3) Operations and jobs to be carried out at the process schedule worker room

Various analysis data are sent from the analysis center (analytical laboratory) to the process schedule worker room. These data are set into the common data input panel punctually in correspondence to heat numbers. When the blowing operation is started, the process schedule and technical data are printed out by means of logging typewriter with respect to the heat before last. Namely, the data transaction (I/O) relating to one heat is carried out over several heats from the viewpoint of time, and the data relating to several heats are therefore existent all the time. The data are processed according to the process schedule, classified as to heat numbers, and are applied for operations sequentially.

3) Operations to be carried out once every day or more less frequently:

These operations are usually conducted on the operator console in the computer room. The statistical data of production operations and goodness-of-fit dispersions are collected every day. The results are reported by the worker who attends 8 a.m. or thereafter and works the typewriter in the computer room.

The log sheet and technical data that have not been printed out can also be printed out by the logging typewriter with respect to a designated heat number at a desired time until which they have been collected.

In addition, the preliminary processing required before entering into the periodic inspection and the processing which is required in order to connect the computer control system to the operation system on line can be accomplished on the console by starting specific programs. The computer carries out automatic checking of each I/O unit once every day.

VI. MATHEMATICAL MODELS FOR CONVERTER PROCESS

The mathematical models required for the computer control of the converter process vary largely depending on the operation systems. In a broad sense, however, they may be classified into the following mathematical formulae.

(1) Hot metal weight calculation formula
(2) Flux feeding rate and weight calculation formula
(3) Oxygen feed rate calculation formula
(4) Alloying element weight calculation formula
(5) Lance position calculation formula

Strictly stated, however, these are not independent, but closely related to each other. The mathematical models for the end-point control of the converter process can roughly be divided into static model and dynamic model. The former is to obtain the required parameters by taking into account material balance and heat balance in the converter being reckoned as a closed region with all chronological processions discarded. In this method, the data during blowing work can totally be neglected. On the contrary, chronological reaction processes are taken into consideration in the dynamic model. Methodologically, there will be available a theoretical model which is set up by taking into account the physical and chemical rules, quantities, etc.; a statistical model in which modeling is dependent solely on the statistical techniques; and a compromise model. As stated above, there are various methods for making up mathematical models. In recent years, the tendency for the dynamic model to replace the static model has been noticed as the computer control system has progressed both in its control accuracy and reliability and practising techniques.

VII. CONCLUSION

LD converter process is a kind of batch process, and greatly counts on manual work. Unlike the ordinary processes, its design performance has to be done with special consideration. We are fully convinced we have established a foundation of the computer control system for LD process through many years of experience.

The whole field of process control systems is still undergoing rapid changes. The contents in this text and preconceived notions may become obsolete in a short time. Our continued efforts will be dedicated toward the development of more improved control systems.