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COMPUTER CONTROL FOR LD CONVERTER

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I. INTRODUCTION

From 1964, Fuji Electric has produced 10 LD converter computer control systems but recently, a new system has been delivered to the Kakogawa Works of Kobe Steel. The features of this system are as follows:

1) A wide range of displays on color cathode ray tubes (CRT) with keyboards attached is employed. Requests are made to the computer by keyboard operation and the computer answer is displayed on the CRT.
2) Models are used in the operation for research and development but the process control is in the hands of the local operators. The experience and judgement of the operators are utilized which are important for increased morale.
3) Data check CRT displays are utilized for completing and repairing damaged data.
4) Special telephones are provided in the data setting panels to permit close communication in the plant.

This system is described in the following sections.

II. OUTLINE OF CONVERTER PROCESS AND COMPUTER SYSTEM COMPONENTS

1. Converter Process Outline

Converters (or LD converters) are crucible type rotary furnaces. The time chart is shown in *Fig. 1* but they are actually operated on the basis of batch processing.

As primary materials, scrap and hot metal are inserted and as flux, lime, iron ore, mill scale, fluorites, etc. are precharged. The lance is lowered and pure oxygen is blown on the hot metal surface from above. The Si and P components are oxidized by the oxygen blowing and slag is formed by reaction with the precharged lime. The C in the hot metal is burned and the majority becomes CO gas. A part is converted into CO_2 gas and exhausted out of the converter. The hot metal and slag in the converter are strongly agitated by jets of oxygen and the CO gas formed. The reaction is thus pro-

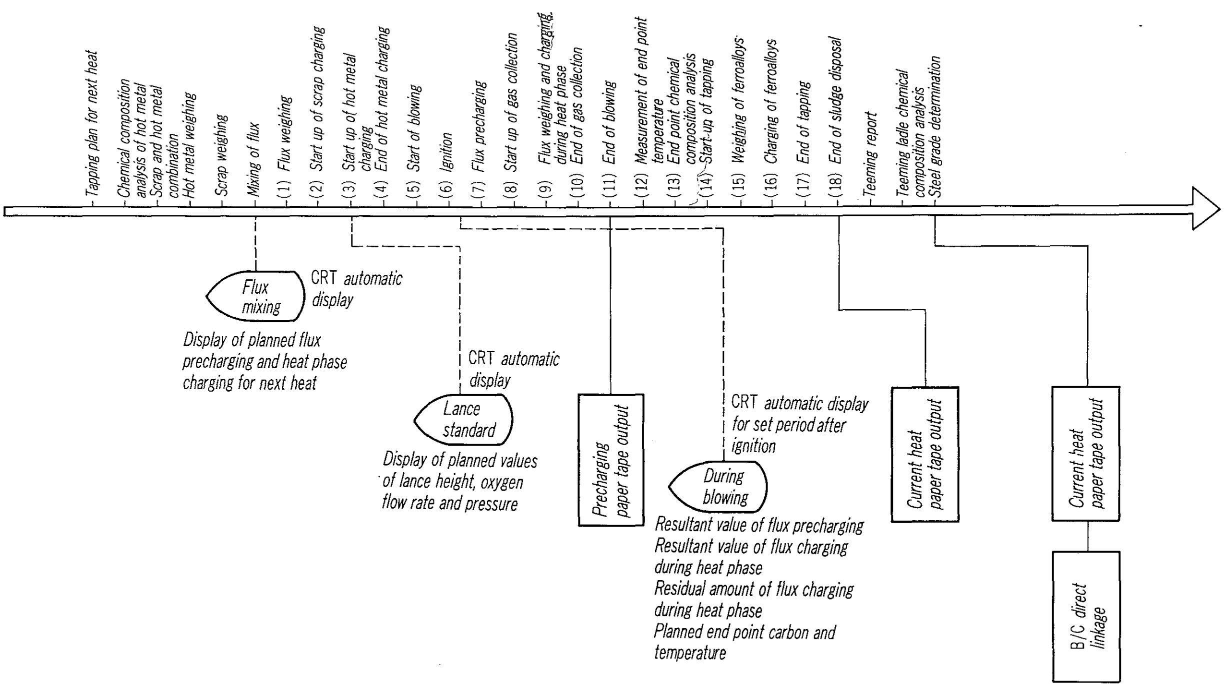

Fig. 1 Timing chart of LD converter

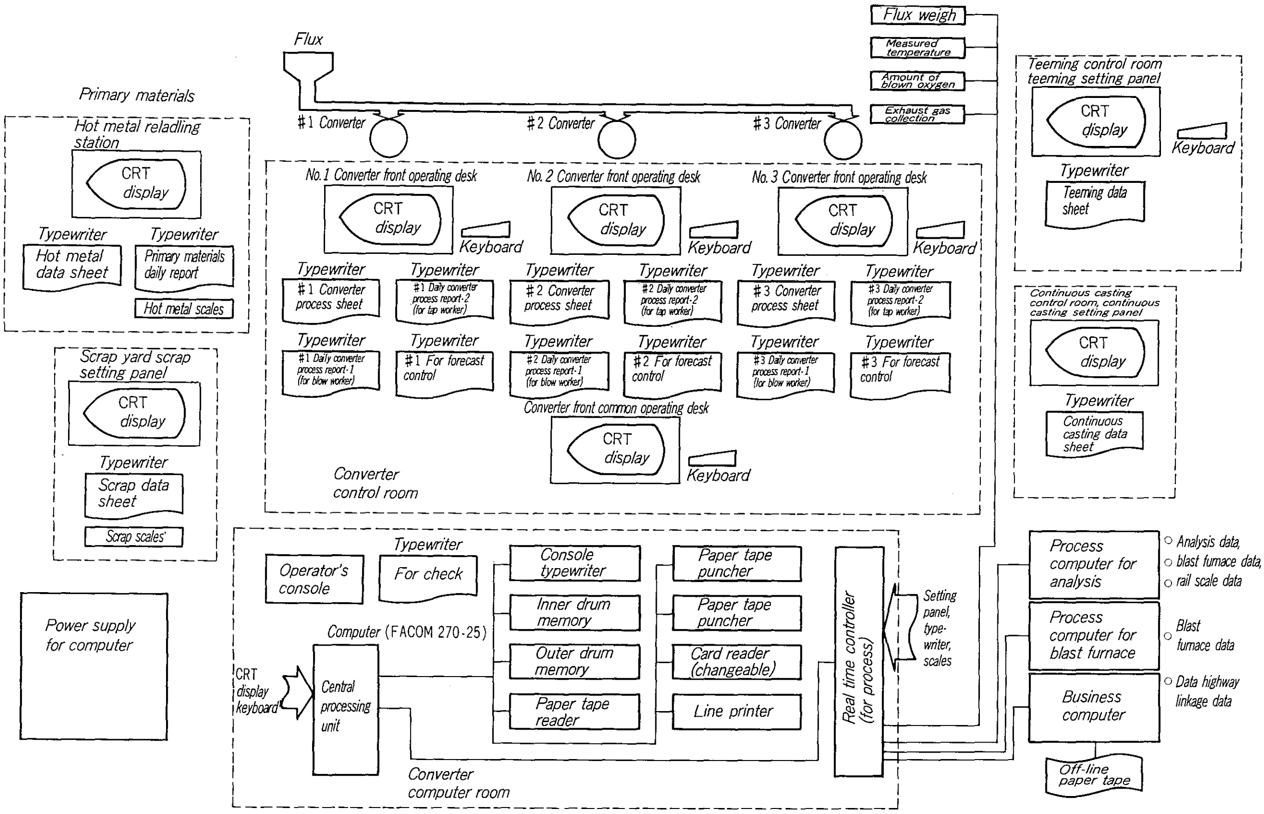

Fig. 2 Skeleton diagram of hardware

moted and refining occurs.

When the blowing is completed, the hot steel temperature is measured and samples for chemical composition analysis are collected. If these results indicated the temperature and composition are as planned, deoxidizers, ferroalloys, etc. are added in accordance with requirements. While the composition is regulated, tapping is performed. When the results differ from the planned values, reblowing and cooling are performed but since these operations greatly reduce the converter operating efficiencies, they must be avoided as much as possible.

The tapped molten steel is brought to the teeming deck, placed in casting molds and teeming is performed or the steel is applied to a continuous caster.

The converter process is a batch process and requires a considerable amount of human intervention.

2. Construction of the Computer System

As can be seen in *Fig. 2*, the FACOM 270-25 computer is used in this process system. Compared with conventional systems, it is noteworthy that the data setting panels are greatly reduced and except for the CRT, no local display panels are used.

III. FUNCTIONS OF THE COMPUTER CONTROL SYSTEM

The functions of this system are as follows:

(1) Data processing
(2) Operators' guide
(3) Linkage with other computers
(4) Forecast control

The above functions are explained below in relation to *Fig. 1*.

1) Data processing

Fig. 1 shows an outline of the converter operation timing chart. Seven color CRT displays are used and the data arising continuously are stored in files for a while. In accordance with the display requirements of the operator, the data are displayed in set patterns. In this system, paper tape is output at the end of blowing showing the operation result values for the previous heat, at the end of sludge disposal showing the planned values for the standard operation and at the time of input of the final steel grades giving final steel grade data.

2) Operators' guide

This system features automatic CRT display which indicates to the operator the standards for the various operations. At the start of tapping of the previous charge, the flux process pattern is displayed on the CRT. At the start of hot metal charging, the lance standard pattern is shown on the CRT. At a set time after ignition, the pattern during blowing is displayed on the CRT. These three automatic display patterns function as the main operator guides of the system. If the operating conditions change, it is necessary to perform standard calculations since the standard values will also change. The various coefficients required in the computer system in such cases can be revised from the operator's console.

3) Linkage with other computers

The results on the paper tape outputs explained in 1) on data processing are used as data for a business computer. The steel grade final data are sent to the business computer by direct linkage via a process interface (hereafter referred to as RTC).

The data processing computer for analysis sends the results of the chemical composition evaluations at various stages in the converter process to the converter computer by direct linkage via the RTC. The tapping plans and final steel grade data are sent from the converter computer to the analysis computer.

The process computers for the blast furnace transmit only to the converters and not vice versa. The contents of the data transmissioned include operating conditions of the blast furnace and planned tap amounts. These data are displayed on the converter CRT.

4) Forecast control

The purpose of the converter computer control is to ensure the planned end point carbon and temperature of products. There are two types of control: static control in which instructed from the conventional CRT keyboard the amounts of flux, oxygen, etc. to be used are calculated; and dynamic control in which the amounts of flux and oxygen to be used are calculated using data from measurements of steel bath carbon, temperature and oxygen and digital output is given for the oxygen flow rate, lance position set values, etc.

1. Tap Planning and Primary Material Control

1) Tap planning

Tap planning corresponds to the ordered steel grade data (data of steel grade, type of mold, order number etc. represented by the order number) and the charge number. In this system, this correspondence is input directly from the keyboard on the CRT. When the plan is established, it is sent to the analysis computer. A chemical composition analysis is performed in the analytical laboratory when samples from the ladle collected at the time of subsequent teeming or continuous casting for that charge number are sent from the factory. From these results, a check is made concerning the planned upper and lower limits for the various components. Data are transmitted concerning chemical composition and any deviations from the standard values. These results are used as reference when the operator decides the steel grade and when there are deviations from the standards, appropriate steps are taken by operating the CRT keyboard. The tapping plan pattern on CRT shows data from the past, present and future heats. The display colors differ in each case and it is possible to evaluate the heat conditions in each case at that time by looking at the display. The pattern is changed automatically (removals from the pattern, color changes, etc.) when the tapping completion signal is received. Changes in the plans can be made any time from the keyboard. A transmission is made again to the analytical laboratory and is used for subsequent checks in the laboratory. Data other than the charge number and order number are set on the keyboard and the continuous casting data set panel. These patterns can be viewed not only in front of the converters but also from the continuous casting and teeming stations, and the operators in these locations can also understand the converter operating conditions.

2) Scrap and hot metal combination

The combination of the primary materials, i.e. hot metal and scrap, is decided by the planned steel grade, tap yield, etc. and in order to give these data to the operators, the scrap and hot metal combination pattern can be displayed on the common CRT on call. A special method is used for handling the tap yield.

From these CRT data displays, the operator can understand how the primary materials should be combined for the current heat and if the necessary planned values are set from the CRT keyboard, the weights of hot metal and scrap are calculated and displayed.

3) Hot metal

In order to determine the specified amount of hot metal in the primary materials combination pattern, the composition and weight data of the hot metal in the torpedo car are necessary. There are two ways to obtain the composition of the hot metal in the torpedo cars: one is to calculate the average values from the samples at the time of placing the metal from the blast furnace in the torpedo cars, and the other is to obtain the composition of samples taken directly from the torpedo cars. The weights are also measured when the torpedo car travels between the blast furnace and the converter by means of a rail scale. The planned values of the hot metal weights are set from the hot metal data setting panel for each torpedo car and the weights specified from the combination calculations in the primary materials combination pattern are displayed on the hot metal CRT. In the shop, the hot metal is added to the laddle on the basis of the instruction and if the weighing is complete, the weight data are stored and displayed on the hot metal CRT and the CRT's for each converter. If there is a mistake in the setting of the hot metal weight or the torpedo car number, the results can be revised.

The temperature of the hot metal in the ladle is measured and the sample in the ladle is analyzed.

4) Scrap

Scrap which is one of the primary materials is weighed in the scrap chute beforehand for the planned heat and when the heat begins, it is inserted into the converter.

The scrap can be classified into scrap iron and cold pig iron. The former differs from the latter considerably in respect to chemical composition, etc. At the time of weighing, the descriptions of the scrap to be weighed and their weights are fed in from the setting panel in the scrap yard in accordance with the specified combination values and are displayed on the scrap CRT as the planned weight. When the operator then performs the actual weighing in accordance with these planned values, the actual resultant values are shown in the CRT display. When the weighing is completed, the scrap data sheet is printed out by the typewriter in the scrap yard.

2. Converter Operation

The converter operation mentioned here refers to the operations from the flux weighing to the completion of sludge disposal as shown in the timing chart in *Fig. 1*. These various timing operations and the computer processes will be explained here.

1) Flux weighing

The set weights for all precharging flux calculated beforehand from the flux process CRT pattern are viewed and the flux station worker sets the weights for each type of flux and performs the weighing.

2) Start up of scrap charging

The scrap in the chute which has been weighed beforehand by the scrap scale is inserted into the converter. The data related to the scrap and the operation time data are renewed.

3) Start up of hot metal charging

The hot metal in the ladle which has been weighed beforehand by the hot metal scales is inserted in the converter. The computer changes the file concerning the hot metal, calculates the required standard values, gives automatic access to related patterns, etc.

4) End of hot metal charging

The computer is informed of the end of hot metal charging manually. The time required for hot metal charging is calculated.

5) Start up of blowing

The lance is lowered by pushing the blowing start button and oxygen blowing takes place when the lance reaches the specified position. The program which reads the oxygen flow and lance position during the blowing begins, data are transmitted to the analysis computer and the files related to the ferroalloys and coolant are changed.

6) Ignition

The ignition which occurs due to the combustion of carbon when the oxygen jet is blown against the hot metal surface is evaluated visually by the main pulpit worker who pushes a button. At a set time after ignition, there is an automatic change to the pattern during blowing.

7) Flux precharging

The flux weighed in 1) and kept in a hopper is inserted into the converter and the file is re-edited.

8) Start up of gas collection

Since CO_2, CO and O_2 gases arise in the converter due to decarburization, they must be collected. When conditions in the furnace such as the gas flow and the pressure reach certain constant values, gas collection starts automatically in sequence. The flow rate of the exhaust gas and the compositions of CO_2, CO and O_2 are read in.

9) Flux weighing and charging during heat cycle

Flux including fluorites that improve the fluidity of the slag and increase the reactivity and iron ore and others that act as a coolant is charged during blowing. At the time of charging, the weight of the flux, the time from ignition and the amount of oxygen used are obtained.

10) End of gas collection

The computer is informed of the end of gas collection in the same sequence as for the start of gas collection in 8). The volume and composition etc. of the gas are calculated.

11) End of blowing

When the amount of oxygen used reaches the planned value, oxygen blowing stops and the lance is raised. The various data collected during blowing are processed and a paper tape is output.

12) End point temperature measurement

The steel bath temperature in the front of the converter after blowing stops is measured. The result is simultaneously accomodated in a file and printed out by the typewriter in front of the converter.

13) End point chemical composition analysis

At the same time as the measurement of the end point temperature as in 12), the molten steel is sampled and analyzed. The results are transmitted from the analysis computer and simultaneously accomodated in a file and printed out by the typewriter in front of the converter. If the end point temperature and composition are as planned, the tapping operation starts but if they are not, there are reblowing and further flux charging.

14) Start up of tapping

The converter is tilted and the molten metal in the converter is transferred to the teeming ladle. At that time, the weights for the precharging and heat cycle charging of flux for the next heat are calculated and the flux process pattern is automatically displayed.

15) Ferroalloy weighing

Ferroalloys are added to the teeming ladle in order to adjust the steel composition to the final specified values. The weights of the alloys are measured.

16) Ferroalloy charging

The ferroalloys in the amounts measured in 15) are charged into the teeming ladle.

17) End of tapping

When the tapping from the converter to the teeming ladle is completed, the files related to the

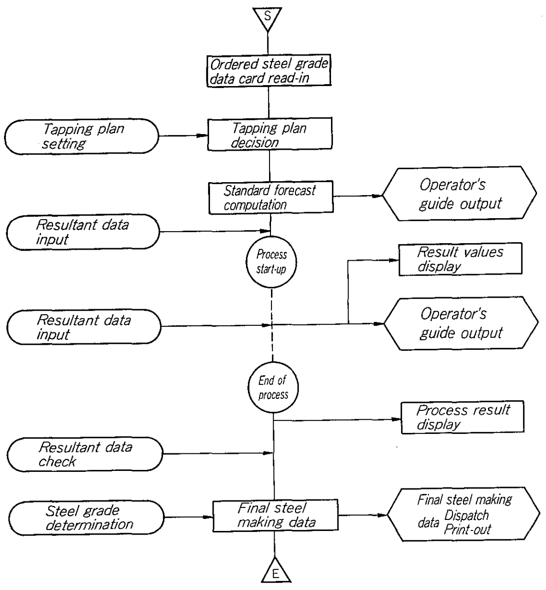

Fig. 3 Schema of data

converter operating conditions are changed and the tapping time is calculated.

18) End of sludge disposal

After the tapping, the sludge must be disposed of in the sludge disposal ladle. The time data are calculated, the files related to the final steel grade are changed and the current charge data are output on paper tape.

3. Steel Grade Setting

The operations are performed in accordance with the tapping plan operating instructions but the planned steel grade will not be achieved if some unexpected outside disturbance occurs even when the operations are as specified or when the operations can not be performed as specified for some reason. At such times, it is impossible to handle the tapped steel as the steel of the tapping plan and it is necessary to change the steel grade.

The steel grade determination involves determining what grade the tapped steel is to be handled as, printing out the final grade data and transmiting the data to the business computer, etc. *Fig. 3* shows the role of the steel grade determination in the converter operation.

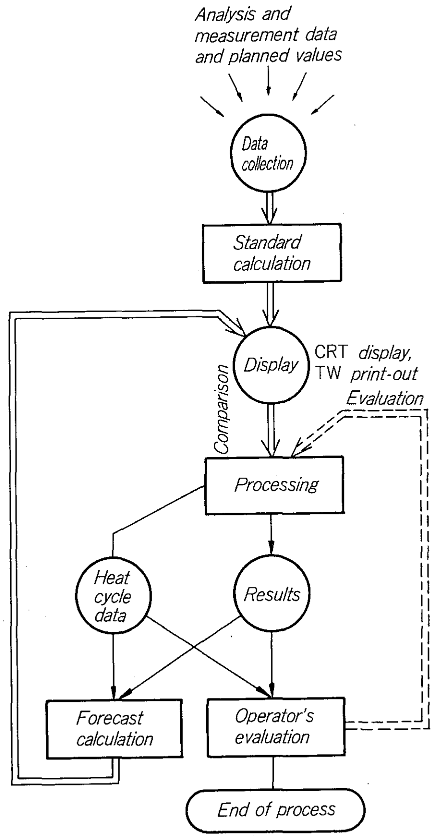

Fig. 4 Flow chart of operation for calculation of standard values

4. Others

1) Standard calculations

These calculations provide standard values for the various operations from measured, analyzed and set information beforehand in order to guide the operators. Even when the operations are performed

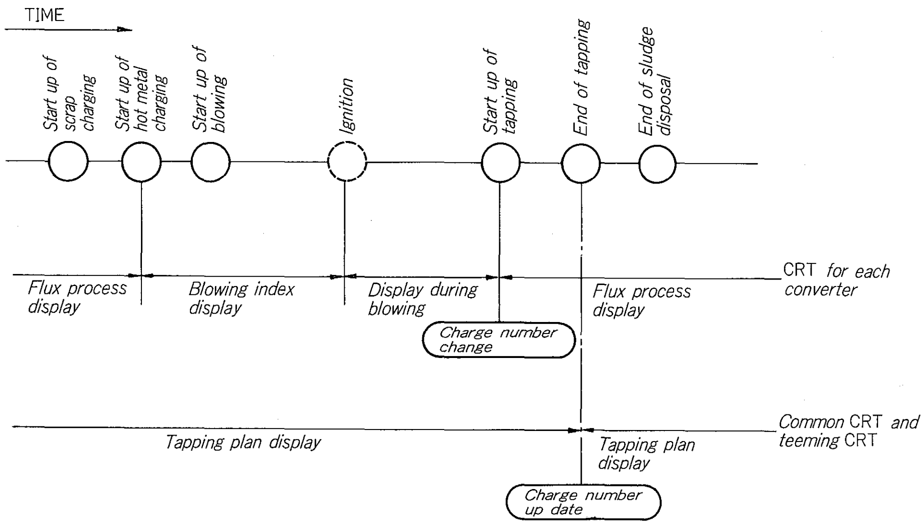

Fig. 5 Timing chart of self-changing picture

Table 1 List of self-changing displays

Display name	PATTERN No.	Display time	CRT display	Main display contents
Flux process display	210	Start-up of tapping of previous heat ⟶ Start-up of hot metal charge of current heat	Each converter	Flux standard values and primary materials data
Blowing index display	220	Start-up of hot metal charge of current heat ⟶ Set time after ignition in current heat	Each converter	Lance standard values, primary materials data, standard values for end point temperature and C
Display during blowing	230	Set time after ignition in current heat ⟶ Start-up of tapping of current heat	Each converter	Flux planning values, actual values, planned values for end point temperature and C
Tapping plan display	130	End of tapping of previous heat ⟶ End of tapping of current heat	Common for all converters Teeming, continuous casting	Tapping planning

Table 2 List of keyboard operations

$\triangleright Y\sqcup G_2G_3G_4\ R_Q$
$\triangleright Y\sqcup G_2G_3G_4\sqcup\ D_1D_2D_3\ R_Q$
$\triangleright Y\sqcup G_2G_3G_4\sqcup\ AX_1X_2X_3X_4\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ X\cdots\cdots X\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ AX_1X_2X_3X_4\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ AX_1X_2X_3X_4X_5\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ A_1A_2X_1X_2X_3X_4X_3\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ A_1X_1X_2X_3X_2\ R_Q$
$\triangleright S\sqcup MM\text{-}N\sqcup\ {*}C_1C_2{*}\sqcup X\cdots\cdots X$ $\sqcup{*}C_3C_4{*}\sqcup\ Z\cdots\cdots Z\ R_Q$
$\triangleright K\sqcup\ MM\text{-}N\ R_Q$
$\triangleright K\sqcup\ Y\ R_Q$
$\triangleright T\sqcup MM\ R_Q$
$\triangleright R\ R_Q$
$\triangleright C\ R_Q$
$\triangleright DL\ R_Q$

Y : manual display summons
S : setting (also revision)
K : calculation
T : cancellation
R : related display update
C : automatic pattern display after cancellation of manual display
DL··direct linkage
$G_2\cdots$, $D_1\cdots$,
$X_1\cdots$, $C_1C_2C_3C_4$ (decimals)
MM : line (decimals)
N··string (decimals)
A, A_1, A_2, A_3 : alphabet
R_Q : request button

according to these calculated values, the actual operations deviate from the calculated but the feedback of the operation data is not performed by the standard calculation program and is revised by the forecast calculations. The standard calculations are known as static calculations and the forecast calculations as dynamic. *Fig. 4* shows the flow chart for the calculations and operations. The standard value calculations are as follows:

(1) Standard end point carbon and temperature calculations
(2) Standard flux calculations
(3) Desulphurizer calculations
(4) Standard lance height and oxygen amount calculations
(5) Recent tap yields and hot metal ratios
(6) Recent TFe, O and C

2) CRT displays

When classifying CRT displays, there are two types: displays which show automatic changing patterns due to converter operation and dislpays to which there is rapid manual access. The former consist mainly of standard calculation patterns and are important for operations such as flux combinations and the oxygen blow index. The latter are not required every time and are for checks of order numbers, previous heats, etc. The automatic changing displays are automatically changed whenever there is any addition to or change in the displayed data. The manual access displays can be viewed at all times and even when there is an automatic change in the other displays when the manual access displays are being viewed, the manual displays do not change although return to the automatic changing displays is possible by keyboard operation (for the changeover timing and types of automatic changing displays, refer to *Fig. 5* and *Table 1.*

In this system, the most difficult problem is to determine how to divide and process a large amount of data for CRT display, the composition of the CRT pattern, the manual request method and the CRT answer method. Since almost all of these points are compiled in nearly standard forms, they can be used not only in future converter computer systems but also in other process control systems. A detailed explanation is not given here but the request patterns are as shown in *Table 2.*

3) Data transmission

At present the converter computer has data transmissions with three outside computers:

(1) Process computer for analysis
(2) Process computer for blast furnace
(3) Business computer (data center)

The contents for these data transmissions are explained below.

1) Process computer for analysis

The data transmitted from the BOF shop to the analytical laboratory are composed of ordered instruction data determined by the tapping plan and final instruction data when the steel grade is determined. The data sent from the analytical laboratory to the BOF shop are hot metal rail scales data, blast furnace hot metal composition data and composition data related to the steel making process. These data are transmitted to the BOP shop on the results collected during the process from the time the hot metal leaves the blast furnace to the time the molten steel in the converter finally reaches the teeming or continuous casting stations. The operators proceed with the operations on the basis of the matching of the steel grade obtained from these analyses with the planned steel grade. The linkage with the analysis computer has three interrupt points: action, data and control. Action interrupt is for the various types of items and number of words of data. Data interrupt is related to each individual data item and the control interrupt conveys the various conditions in which result when the signals are received. In the linkage flow, the action interrupt informs what type of data is being received, the data interrupt supplies the individual data and finally the control interrupt informs that the communication is completed. In this way, communication of one item is completed. The control language includes, in addition to the completion of communication, errors in number of words, data errors, order errors, timing errors and communication abnormalities. When an error occurs other than communications abnormalities, data loss is avoided but when the error occurs even after several trial operations, the communication abnormality is reported as a circuit error and the communication ends in the abnormality.

2) Process computer for blast furnace

Unlike in the case with the analysis computer, no data are transmitted from the BOF shop in this case; they are only received. These data are as follows:

(1) Tapping starting time
(2) Tapping finishing time
(3) Blast furnace operating conditions
(4) Others

The contents of (3) show if the blast furnace is under blast or not and this information is displayed in different colors on the CRT of the ladle station. Additional information can be displayed on CRT in accordance with requirements of the blast furnace number on the setting panel. The linkage method is exactly the same as that for the analysis computer.

3) Business computer (data center)

At the time of steel grade determination, result values such as the planned instruction data, final instruction data and others are sent to the business computer. The linkage method is such that a sequence is formed for each transmitted word. A data parity check is made by the hardware and a sum check is made by the software. One word of data (16 bits) is broken down into portions of 4 bits each and the sum is obtained. The sum of all the data before the transmission is taken and this is also transmitted as final datum. On the receiving side, the data sent in the form of one word is divided into groups of 4 bits and total is calculated. On the transmission side, the permit signal is returned and the next datum is requested. These complete totals on the receiving and sending sides are checked on the receiving side and when they match, instead of permit, the ACK signal is returned and normal completion occurs. When they do not match, a NAK signal is returned and a request signal is again sent to the sending side. However, when the NAK signal is again returned, there is abnormal completion as a circuit error. Considering the data flow from the hardware system diagram in *Fig. 6*, the data to the BOF shop STATION via the RTC do not enter the STATION on the business computer side directly and are transmitted via other stations (these are connected with other computers). These data are received on the business computer side via SYSTEM 7 where ACK or NAK is determined.

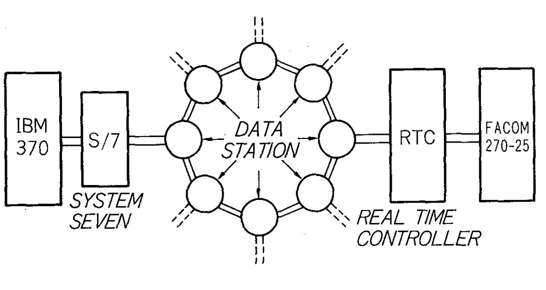

Fig. 6 Skeleton diagram of data highway system

IV. CONCLUSION

The functional estimation of the converter computer is based not only on the ability to process large amounts of converter data efficiently but also on its attractiveness to the shop operators.

This system has been more successful than former converter computer systems in utilizing the experience and judgement of the shop operators, but there are still problems to be solved. Efforts will be made to improve the same kind of system in the future in order to be able to supply a better converter computer system.