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# AUTOMATIC CONTROL SYSTEM FOR HOT BLAST STOVES

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## I. INTRODUCTION

In 1959, Fuji Electric, in cooperation with Kubota Iron and Machinery Works Ltd., delivered the first automatic control system for hot blast stoves to the Muroran Works of Fuji Iron and Steel Co., Ltd. Since that time up to February 1968, Fuji Electric has produced 113 such units (101 delivered, 12 under production). Recently, Fuji Electric standardized the system, and made continuous efforts to improve techniques and lower the cost. Completed system techniques are now available for hot blast stove automatic switching systems and automatic combustion control systems. However, in the last few years, blast furnace equipment has become remarkably large and operation techniques of high temperature and high pressure blowing systems in blast furnaces have advanced considerably. In keeping with these trends, heat consumption in hot blast stoves has been greater than ever before and therefore even a slight rationalization has a great effect on the economics of the system. For this reason, more rationalized control system is required than ever before. To fulfill these requirements, Fuji Electric is now planning various control systems, some of which are now winning the approval of users. An outline of one or two of these systems will be presented in this article.

## II. HOT BLAST STOVE CONTROL SYSTEM

Hot blast stove control system is made up of the 3 devices listed below:

1) Valves for switching
2) Automatic switching device
3) Instrumentation device (automatic combustion control device and hot blast temperature control device).

Of these three, the Kubota Iron and Machinery Works Ltd., which cooperates with Fuji Electric in the manufacture and sales of hot blast stove automatic control systems, is in charge of manufacturing the first system, while Fuji Electric handles the latter two systems.

At present, the most important requirements concerning hot blast stove automatic control systems are

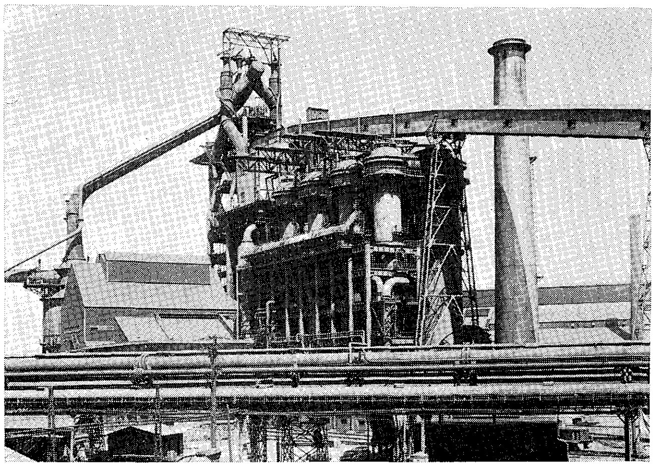


*Fig. 1* External view of hot blast stoves

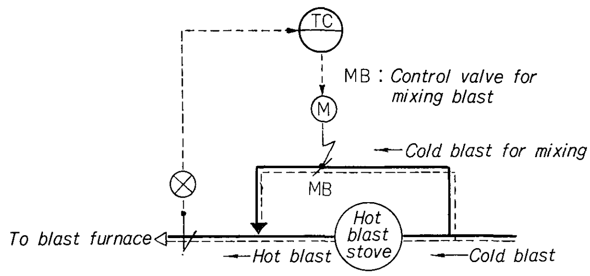
1) Improvement of heat efficiency
2) Improvement of reliability

The parallel blowing system and electronic control computer described below are considered effective in improving heat efficiency. Electronic type measuring equipment and the contactless automatic switching device are effective in improving reliability.

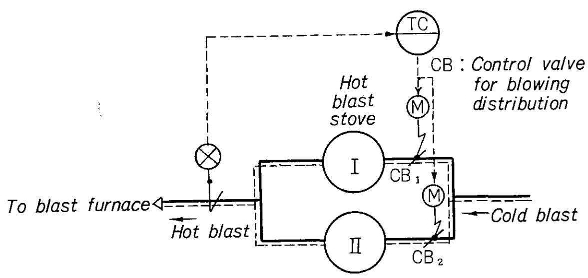
### 1. Parallel Blowing System for Hot Blast Stoves

In hot blast stoves, a very large amount of heat is transferred from fuel during blowing and thus the heat efficiency of the hot blast stove has considerable influence on the cost of pig iron. In hot blast stoves, one way of improving the heat transfer efficiency is by means of the parallel blowing system. This blowing system is known as overlapped parallel blowing or staggered parallel blowing and is applicable when the hot blast stove consists of 4 main units (when there are only 3 units, partially overlapped parallel blowing is possible). Up to the present, hot blast blowing toward blast furnace was generally blown through a single hot blast stove unit and since temperature of the hot blast is higher than the specified blowing temperature for the furnace, it must be controlled by mixing with cold blast which by-passes the main blowing pipe (*Fig. 2* (*a*)).

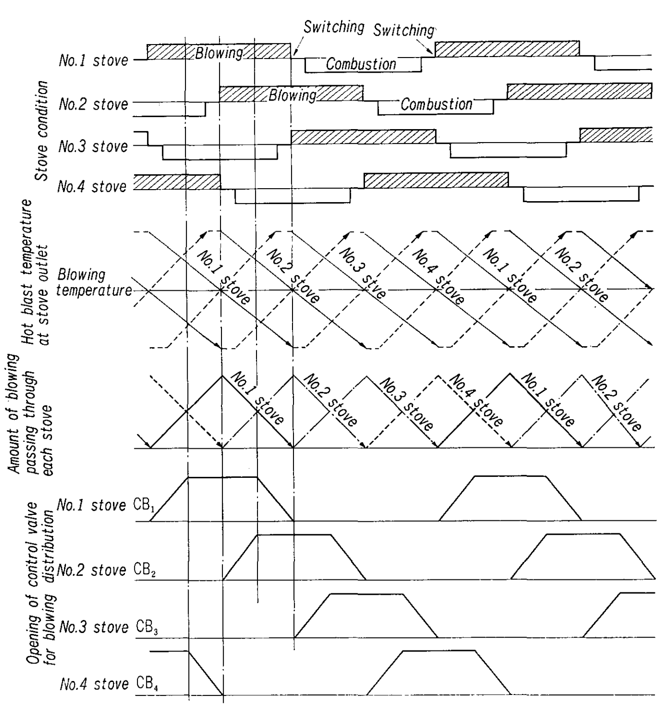
With the overlapped parallel blowing system, 2



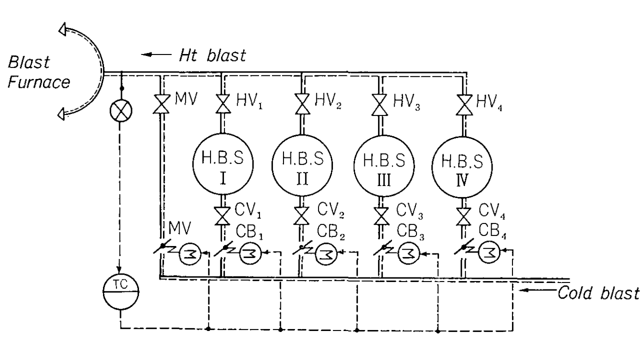

(a) Single blowing




(b) Parallel blowing




(c) Hot blast temperature control for parallel blowing




(d) Blast blowing diagram

*Fig. 2* Hot blast temperature control system

hot blast stove units are always used for blowing, and cold blast passes through the 2 hot blast stove units in parallel (*Fig. 2* (*b*)). Only 1/2 of the blowing cycle of the two hot blast stoves overlaps (*Fig. 2* (*c*)). Therefore, the blowing to the blast furnace consists of a mixture of high temperature hot blast which passes through one hot blast stove retaining its total heat content, and low temperature hot blast which passes through another hot blast stove losing much of its original heat content. The blowing temperature is controlled by changing the distribution ratio of the amount of blast passing through these two stoves.

In the single blowing system, the hot blast temperature at the stove outlet can not be decreased below the specified blowing temperature. However, in the overlapped parallel system, this is possible, and it is not necessary theoretically to mix with cold blast. The features of the parallel blowing system are as follows:

1) The temperature difference of the regenerator checker when blowing commences and when it finishes is large. The regenerator capacity thus increases in respect to the unit amount.

2) Waste gas temperature is lowered and heat loss due to the waste gas is decreased. Heat loss due to radiation from stove walls is also lower.

3) Since the temperature difference between the checker and gas generated during combustion is large, heat displacement efficiency is high, which means large heat savings.

4) Compared with the single system, blowing takes almost twice as long and therefore the percentage of time needed to switch the stoves becomes relatively small and the operating efficiency of the hot blast stoves is improved.

Control of the hot blast temperature in the parallel blowing system is carried out as follows. For example, just after switching from parallel blowing of the 4th and 1st stoves to that of the 1st and 2nd

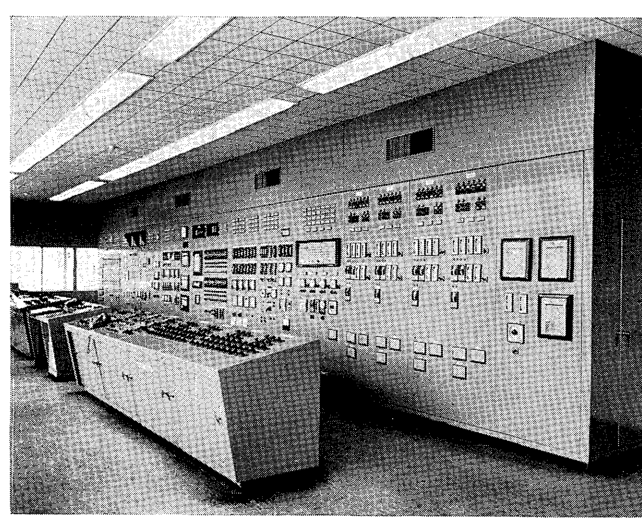


*Fig. 3* Instrument panel and operation desk for hot stove control system

stoves, temperature control can be explained as follows : at this time, the temperature at the 1st stove hot blast outlet is the specified blowing temperature and the total amount of blowing passes through the 1st stove, with the blowing control valve in the 2nd stove (hereafter called $CB_2$) closed completely. At this time, if blowing is continued, the blowing temperature decreases with time and a control signal is sent from the temperature controller to $CB_2$. The temperature controller used is an S-series Teleperm S Controller which is operated by pulses with lengths equal to the increase or decrease of the control signal in accordance with

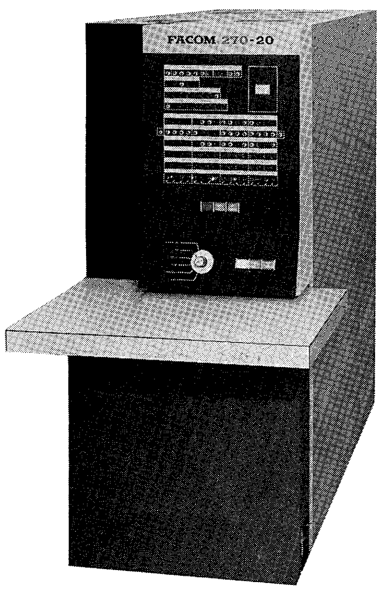



*Fig. 4* Electronic computer for control, FACOM 270-20

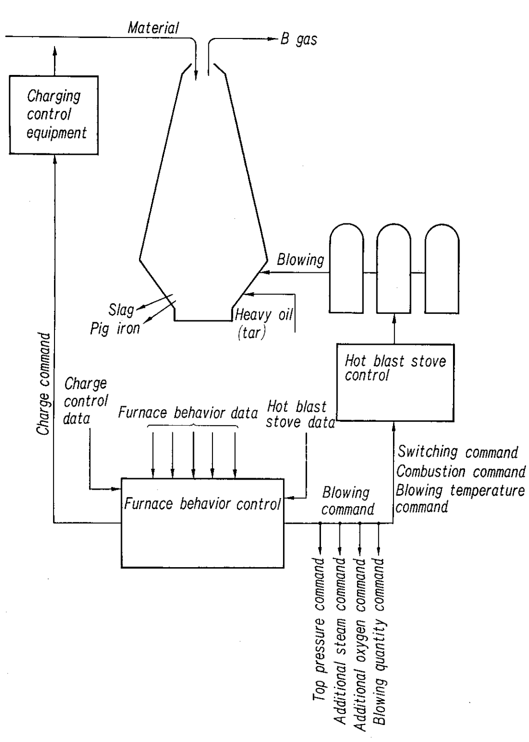



*Fig. 5* Schematic diagram for blast furnace control

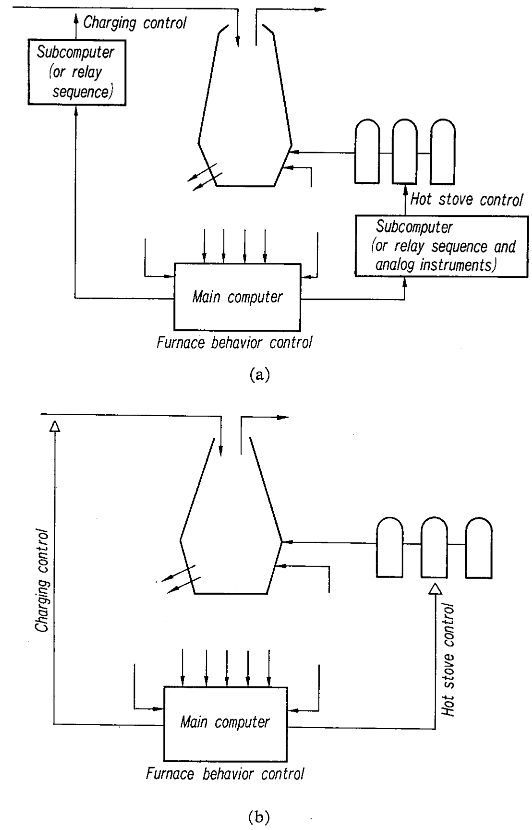



*Fig. 6* Computer system for blast furnace control

polarity variations. $CB_2$ is gradually opened, the blowing resistance ratio of the 1st and 2nd stoves is altered and the percentage of blowing passing through the 2nd stove increases. In other words, the hot blast temperature is controlled by mixing the high temperature hot blast with the low temperature hot blast. At this time, control continues and when the opening rate of $CB_2$ becomes equal to that of the 1st stove blowing control valve (hereafter referred to as $CB_1$), the present limit switch operates to maintain the $CB_2$ opening rate. After this, the control signal switches to the $CB_1$ circuit and simultaneously the control signal variation polarity is reversed. At this time the amount of blowing passing through the 1st and 2nd stoves is approximately equal. As control continues, when $CB_1$ is nearly closed, 3rd stove blowing is made ready to begin. When $CB_1$ closes completely, blowing starts simultaneously through the 3rd stove, which results in parallel blowing through the 2nd and 3rd stoves. The blowing to the blast furnace never stops even for a very short time. If some sort of accident should occur with this parallel blowing system, and the sum of the opening rates of the blowing control valves of 2 stoves should drop abnormally during blowing, normal blowing could not reach the blast furnace. For this reason, the control system must be set for the minimum sum of opening rates.

Tests have been performed on the main equipment to be used in the parallel blowing system and these tests confirm the heat economy features of the system.

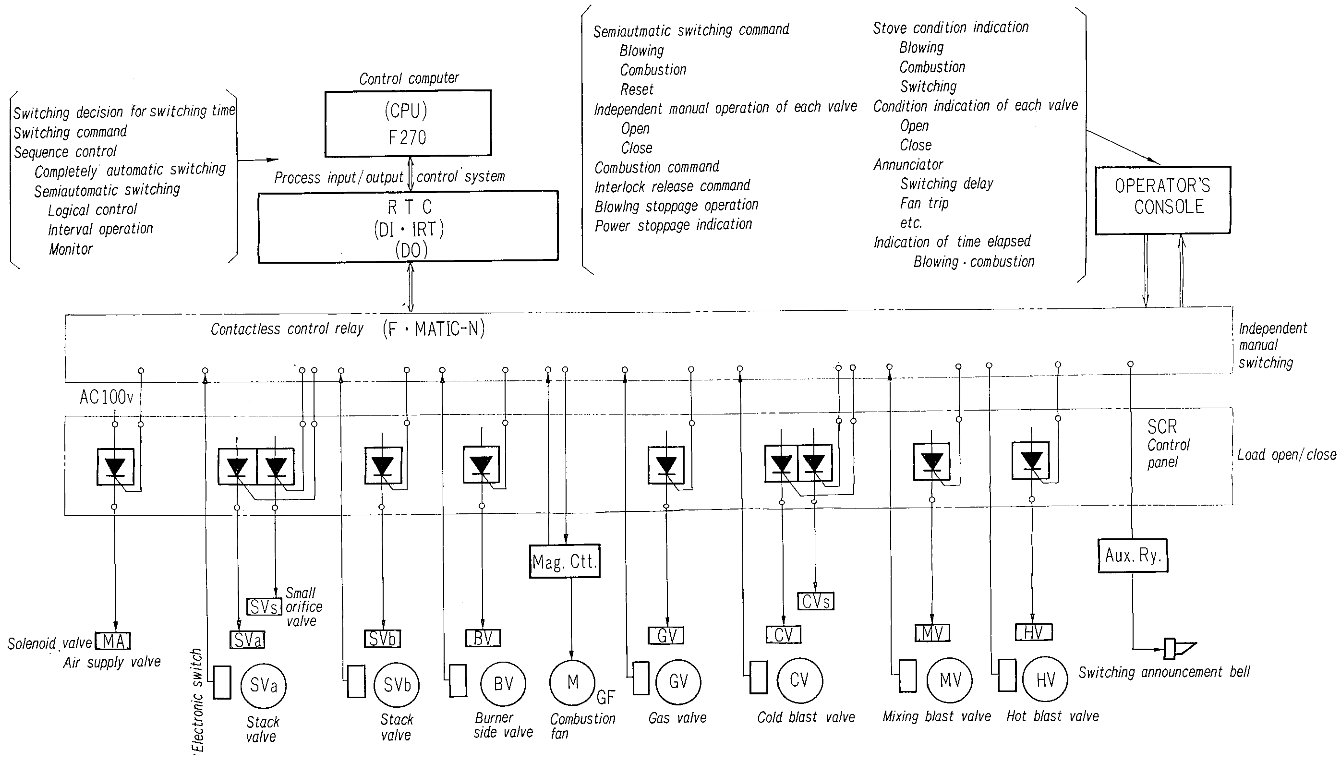



*Fig. 7* **Block diagram of automatic switching device for hot blast stoves using contactless control**

## 2. Applications of the Electronic Control Computer

Recently, electronic computers have been used widely for calculations in all blast furnace techniques. The ultimate aim in the application of these computers is the control of blast furnace behavior.

To control blast furnace behavior, it is necessary to use a computer system with operator and memory capabilities somewhat above medium scale. This is closely related to the JOB control capacity of each of the following:

1) Blast furnace behavior analysis (Real time control of blast furnace behavior data).

2) Charging control (component composition command in accordance with blast furnace behavior).

3) Blowing control/hot blast stove control (blowing command in accordance with blast furnace behavior).

These items must be planned in accordance with production and economic considerations for the entire blast furnace process. When considering the hot blast stoves, as equipment attached to the blast furnace, it is not sufficient to consider the automatic combustion control device and the automatic switching device merely as individual factors in the hot blast stove process; consideration must also be given to achieving optimum schedule operation and optimum combustion control for the blast furnace.

The two systems developed for using electronic computer in blast furnace are shown in *Figs. 6* (*a*) and (*b*). Unifunctional subcomputers for charging control and hot blast stove control or the regular control system can be used. These systems are operated automatically by an operational command sent from the main computer to control blast furnace behavior. Local control systems are not employed for the most part blast furnace behavior control and the sequence controls are all contained in the main computer. Although there have been many debates concerning the advantages and disadvantages of both systems, at present, system (a) is considered safer in the rare event of a computer accident.

The portion of the (a) system computer control method used for hot blast stove control will be discussed below.

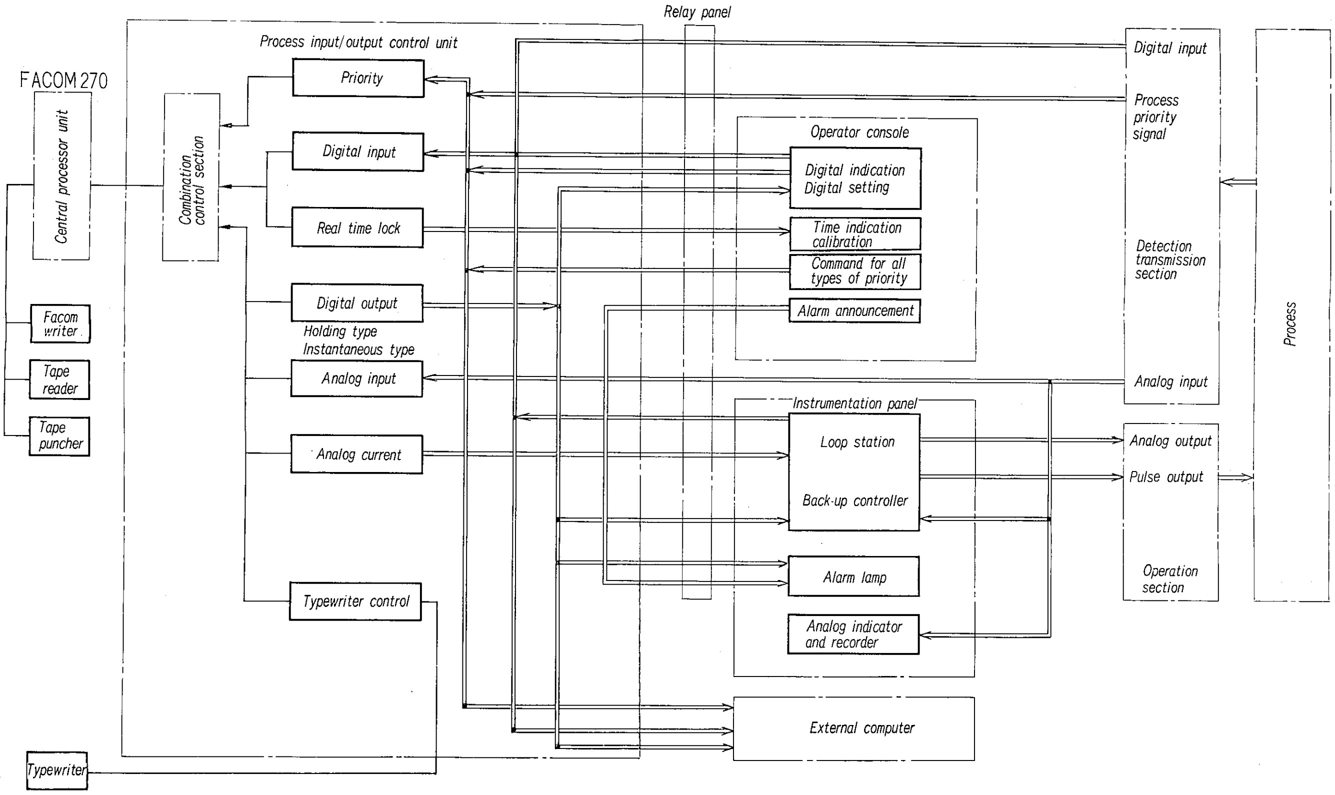
1) Hot blast stove automatic switching control

To assure highly efficient blast stove operation, the parallel blowing system described previously is effective, but if switching time decision is made by a computer, any interruptions in blowing can be prevented. Comparing the parallel blowing system with the single system, the number of hot blast stove units is increased, control modes are pluralized (parallel blowing or single blowing, totally overlapped parallel blowing or partially overlapped parallel blowing) and, stove condition discriminations become complex (it is necessary to decide the sequence in which 2 hot blast stoves with exactly the same blowing conditions must be stopped). Therefore, it is essential more than ever before to achieve the maximum logical decision capability.

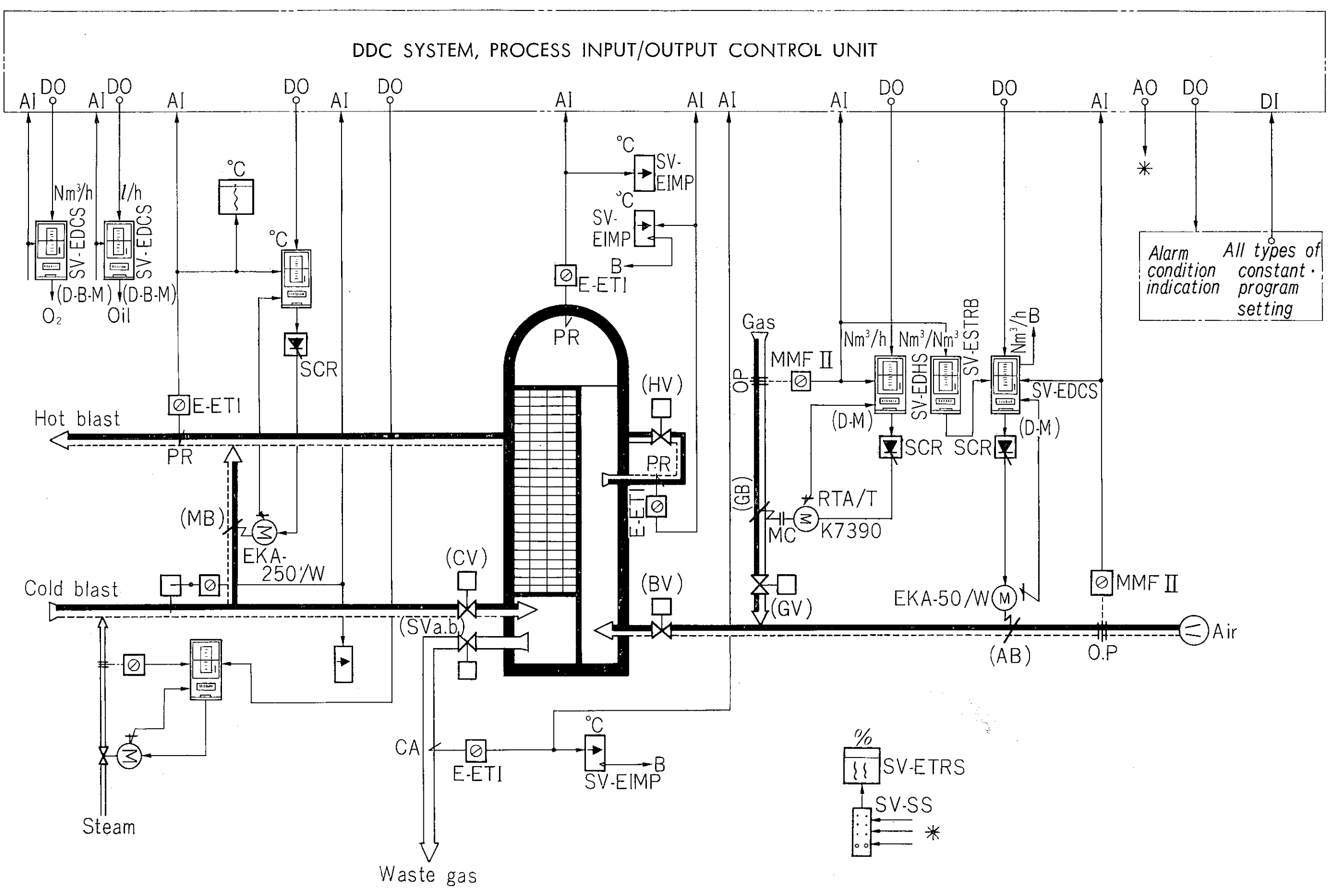
In the hot blast stove automatic switching control systems manufactured previously by Fuji Electric selection could be made between the following four switching systems:

(1) Completely automatic switching

On receiving a signal from the temperature




(a) Fuji DDC system block diagram




(b) System diagram of hot blast stove control system using DDC

*Fig. 8* **Block diagram and system diagram of DDC (Direct Digital control) system for hot blast stoves** meter, the system made decisions concerning the time to stop heat emission and regeneration; selected which stove would be used for blowing and which would be used for combustion, and automatically switched each stove according to the sequence established.

(2) Semiautomatic switching system

The condition (blowing-rest-combustion) of each stove is specified according to a switching command given by the operator, each switching valve is automatically opened or closed in sequence, and stove conditions are switched as specified.

(3) Manual remote switching system

Stove conditions are switched by opening and closing each valve independently according to operating devices for individual valves arranged on a control console and manipulated by an operator.

(4) Manual local switching system

Stove conditions are switched by manual operation of winches attached to each valve.

With switching system (1), the logical decision capability can be exchanged by the computer, basic estimate calculations for termination of heat emission and regeneration can be made with various data from subsequent the hot blast stoves and blast furnace, and the optimum stove operation schedule can be established. When a subcomputer is used, switching sequence control in accordance with the time schedule set on each hot blast stove switching valve is possible. From the viewpoint of reliability, contactless switching sequence circuits, including those in the input/output sections are considered best.

2) Automatic combustion control

In this system the quantity, temperature, and humidity of blast furnace blowing are varied as manipulated variable for furnace behavior control.

First it is essential to plan so that the amount of heat supplied to the blast furnace as sensible blowing heat from the hot blast stoves is neither to much nor too little. For safety, the stoves are generally operated so that there are sufficient heat surpluses to prevent any deficiencies, i.e., it would appear the heat regeneration is ineficient. However, an improvement in heat efficiency is possible by means of combustion control in each unit. Combustion control to keep the amount of fuel to a minimum can be achieved by a computer in order to achieve regeneration of the heat amount determined according to the hot blast stove characteristics and the results of estimated calculations of the heat necessary for the blast furnace. Its manipulated variables are the dome temperature, the amount of combustion gas, the C gas/B gas mixing ratio, the air combustion ratio and the waste gas temperature. When the parallel blowing system is used, combustion time becomes shorter in comparison with that of the single blowing system, and therefore, in order to prevent a deficiency in the amount of heat regenerated, the control system is arranged to terminate the required heat regeneration in the minimum period of time. In the previously described system 1), if the switching schedule is planned basically according to the results of all the various estimate calculations made by the computer, optimum combustion control with minimum heat loss is possible so that the combustion and heat regeneration terminate simultaneously.

When combustion is controlled with a computer, a simple DDC system is considered to be the most effective since initial cost is low, the control loop is simple (necessitating only a simple back-up device), and the DDC system is designed to enable ready connection to the computer.

## III. CONCLUSION

An outline of the parallel blowing system and computer control system for hot blast stoves has been given above under the title automatic control system for hot blast stoves. Two sets of the parallel blowing control systems have already been delivered and one more is now under production. The computer control system using one section of which is described here, is being incorporated in an electronic computer systems for the blast furnace whichh as been ordered and is now being manufactured.

As the users of the computer control systems manufactured so far all confirm the reliability of the equipment, the computer control system described partially here is gradually being included in the on-line system, and will eventually be included in the main program when the blast furnace behavior control model is perfected.