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CONTROL FOR CEMENT FACTORY

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1 INTRODUCTION

Ratio of the energy occupying the manufacturing cost at a cement factory is great. According to the recent statistics in Japan, it has reached about 50%. Out of the energies, fuel is important. Since the year of oil crisis, price of oil has greatly raised. For those non-oil-producing countries such as Japan, it has been an important subject to switch over the fuel from oil to coal because, in comparison with oil, price of coal is more stable, coal can be produced at various areas in the world and even only those collectable can be produced for about 200 years. In Japan, ratio of the cement factories who use the newly developed coal burning equipment has exceeded 86%.

Under the severe energy situation, for cement factory controls, automation system is employed, instrumentation is combined with a computer to execute the optimum control which cannot be done without combination of the instrumentation and computer, minimizing energy consumption, and thus, the method to operate cement factories toward a longer period of time successively and stably has been looked for. This is to fully display the performance of cement manufacturing system so that the productivity per unit energy increases and various expenses required in maintaining the factories decrease.

This paper outlines the cement factories in Japan and introduces the cement factory control methods and control systems manufactured and delivered by Fuji Electric and technical trends in the future.

Fig. 1 Cement factory (NSP kiln)

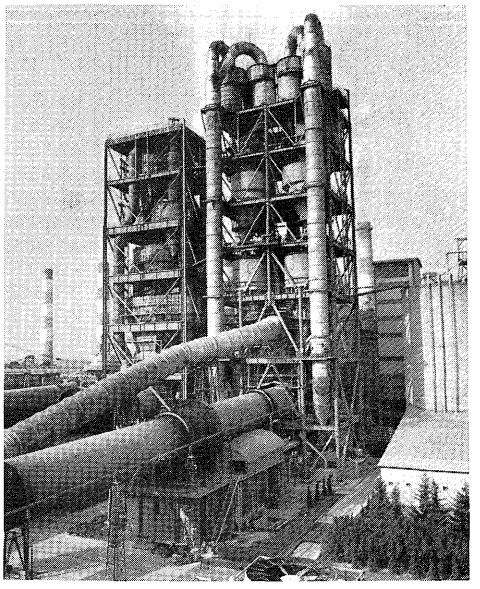
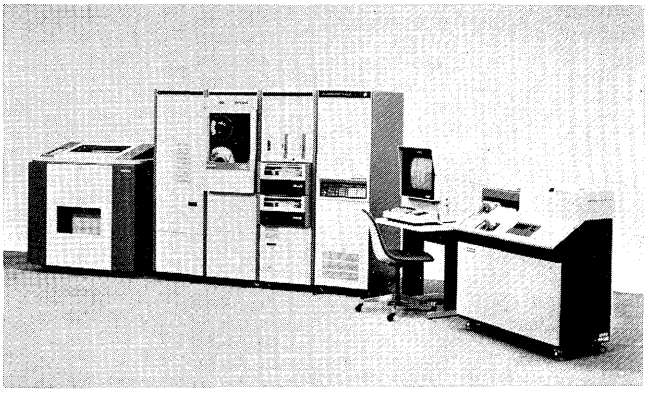


Fig. 2 Process control computer



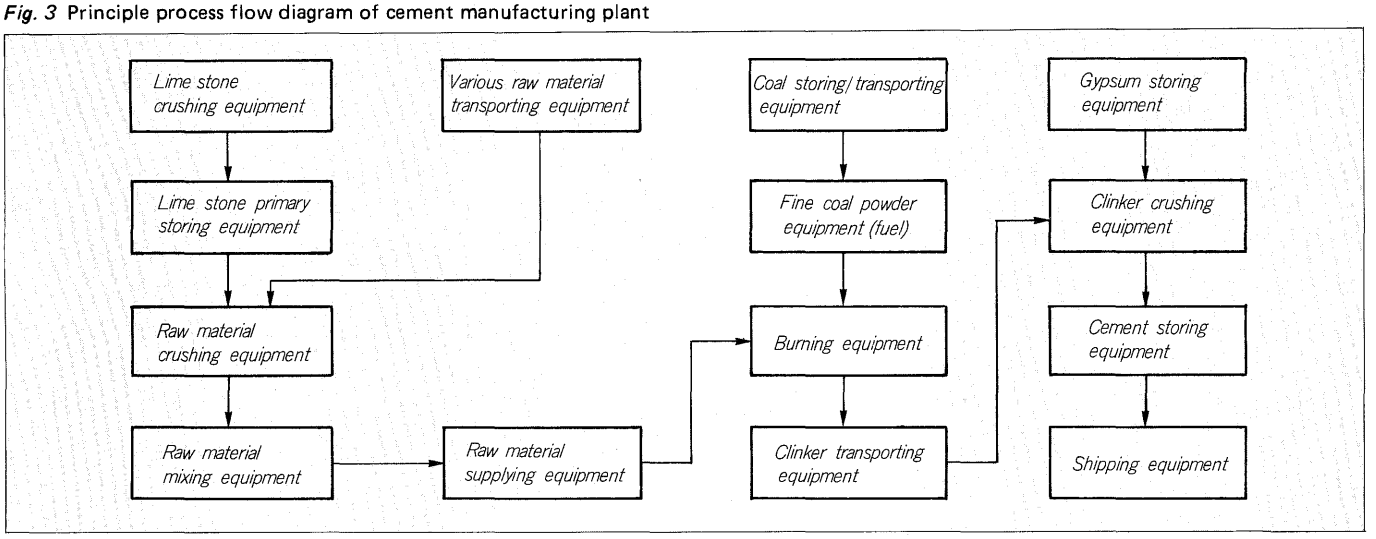
2 CEMENT MANUFACTURING EQUIPMENT

1. Outline of cement manufacturing equipment

As for cement manufacturing equipment, NSP (New Suspension Preheater) kiln which is superior in the energy efficiency and productivity or SP (Suspension Preheater) kiln is the main stream in Japan. And, in many cases, SP kilns have been modified to the more efficient NSP kilns. In 1963, the first SP kiln was operated in Japan, and in 1971, the first NSP kiln developed in Japan was used practically. Almost all the wet type kilns used up to 1963 were renewed to SP or NSP kilns by the early 1970. At present, the main status of cement manufacturing equipment in Japan is as shown below. (36 NSP and SP factories were surveyed. The indicated values are mean values in 1979.)

1) Area of factory premise and number of employees
   215,000 sq.m/Factory, 261 employees/Factory

Fig. 3 Principle process flow diagram of cement manufacturing plant



2) Number of NSP and SP kilns and normally used ability
   (1) NSP kilns: 51; Mean clinker manufacturing ability per kiln: About 4000t/d
   (2) SP kilns: 24; Mean clinker manufacturing ability per kiln: About 2600t/d
3) Lime stone, clinker and cement storing ability (per normally used ability of total kilns)
   Lime stone: 7.7 days; Clinker: 4.3 days; Cement: 5.3 days
4) Kiln driving motor output (Mean value): About 445kW
5) Main induction draft fan (IDF) driving motor output (Mean value): About 2000kW
6) Principle cement manufacturing process

Fig. 3 is the principle process flow diagram of a cement manufacturing plant. However, when the plant uses heavy oil for the fuel, the coal equipment changes to heavy oil tank, etc. There is a coal-oil mexied burning equipment also. It is not shown in the flow diagram, but in the end of the burning equipment, there is a cooler which plays an important role in the cement manufacturing factory. In the burning equipment, heat must be applied to the material at 1300 to 1500°C for a predetermined time. Clinker of high glass component can be obtained by rapidly cooling the material with the cooler after the heating. If the heated material is cooled gradually, components which contained various crystals ($3CaO \cdot Al_2O_3$, $4CaO \cdot Al_2O_3$, Fe_2O_2, etc.) are separated, and hydration (combination of cement with water) is worsened. The clinker crushing equipment is called finishing mill also. The finishing mill mixes and crushes clinker in about 1 cm mean diameter and gypsum ($CaSO_4 \cdot 2H_2O$ or $CaSO_4 \cdot 1/2H_2O$) used as a setting agent, and thus, produces cement as a product. The purpose of crushing is to increase area of reactions as finer the cement powder, the total surface area of each particle is larger.

3 CONTROL SYSTEM IN CEMENT FACTORY

When introducing a control system into a cement factory, verious selections are possible. However, generally, the operations can be briefly classified into a graghic operation and panel-less CRT operation. In both cases, computer and digital equipment are actively employed in the recent systems to accomplich the optimum control and effective supervision. In this paper, a graphic operation equipment is taken up as an example, and introduced. For operations in a cement factory, the instrumentation supervisory control panel made by using acryl or mosaic and installed in the central control room is the main. On the instrumentation supervisory control panel, lamp display, controller, indicator, recorder, etc. are arranged to perform supervision and control. There are many executed controls, and when they are named by each groupm there are raw material crushing control, raw material process control, raw material feeding control, raw material blending control, raw mill control, fuel control, exhaust gas control, kiln cooler process control, kiln control, cooler control, cement transportation process control, cement mill control, electric power demand supervision, etc. Those controlled by the computer are simply controlled by making control status supervisory pictures (about eight kinds) and control constant setting pictures (about eight kinds) on the CRT monitor displays. When using the CRT monitor display, pictures used as a substitution of an indicator (about 32 kinds) and process value trend pictures (about 48 kinds) are mounted as the standard specification.

The main features of the automation equipment, instrumentation equipment and computer system are introduced below.

1. Automation

Cement factories are equipped with an automation equipment, and the automation equipment functions to automatically notify the operators so that the crushing machines and transporting machines more than 200 units can be started and stopped automatically and sequentially, stopped urgently in case of an emergency and proper corrective actions can be taken. Up to about 10 years ago, several thousands of relays are used, while in these several

Fig. 4 Automatic sequence control system

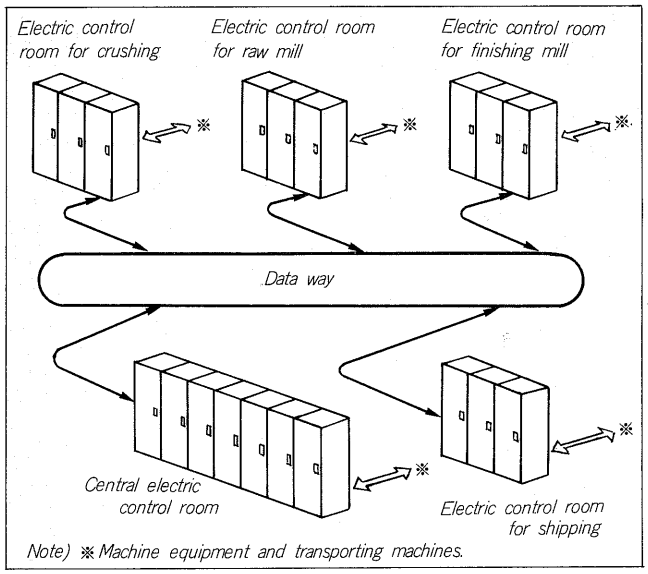


Table 1 General specifications for programmable controller (HDC-100)

Item	Specifications
Control system	Micro-program system
Instructions	Control oriented language
Control function	Constant cyclic control Step sequence control Fixed cycle sampling control Interruption control
Storage capacity	48k words (max.) IC memory
Timer and counter	Total 240 points
Digital input Digital output Analogue input Analogue output High speed counter input	Required inputs/outputs are mounted. Remote I/O system
Power supply	AC 100/110V +10~−15%, 1φ 47~63Hz or DC 110V (DC90~140V)
Insulating voltage	AC 1500V, 1 min.
Ambient temperature, humidity	0~40°C, 20~90%RH
Allowable instantaneous power interruption time	20ms

years, in most cases, programmable controllers are used. In many cases, programmable controllers are installed in several places in corresponding to the individual machines and equipment in the cement factory with wiring distances, etc. taken into considerations. For example, the automatic sequence control system appears as shown in *Fig. 4*. For your reference, general specifications of the Fuji's typical programmable controllers are indicated in *Table 1*.

Table 2 Instrumentation for cement manufacturing industry

Classification	Type of measurement	Name of equipment	Quantity
Detecting device	Temperature	Thermocouple	32
		Resistance bulb	18
		Radiation thermometer	1
		2 color pyrometer	1
	Pressure	Differential pressure transmitter	53
		Pressure transmitter	4
	Flow	Differential pressure transmitter	7
		Area type flowmeter	2
	Level	Sounding level transmitter	15
		Paddle type level switch	13
	Analyzer, others	CO gas analyzer	2
		O_2 gas analyzer	2
		ITV	1
Instruments mounted on the control panel.	Converter, calculator	–	101
	Controller, manual loader	–	76
	Supervisory meter	–	208

2. Instrumentation

To operate cement factories properly and maintain the normal condition, instrumentation equipment such as sensors used to detect temperature, pressure, etc., controllers and actuators used to keep the detected conditions, etc. are essential. Since one overall cement factory has more than 300 loops of monitoring and controlling loop, all of these equipment must be of using ease and trouble-free, and it is one of the important conditions that even if an equipment falls into a trouble, the equipment can be repaired or replaced easily. Further, when preparation of spare parts is taken into consideration, it is desirable to unify models of the used instrumentation equipment. *Table 2* shows major instrumentation equipment used in a newest NSP type cement manufacturing system and the mean quantity of each equipment. Many highly capable instruments are used, and followings are the typical ones.

1) FC series signal transmitter

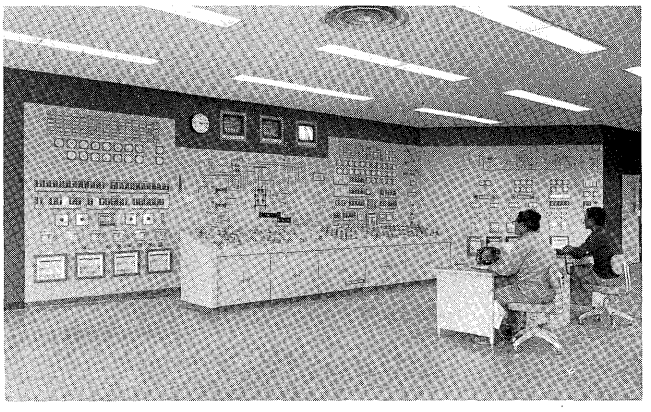
FC series signal transmitters are used to measure pressure, differential pressure, flow, etc. of each part, for example, in the NSP tower. This signal transmitter has a floating cell construction and operates under a capacitance type measuring principle. This instrument features the superior characteristics and high reliability.

2) Compact controller F

The compact controller F is a single loop highly functional digital controller using a microprocessor. This controller is effective in forming a control loop which requires high level calculations particularly when two or more arithmetic operators are required. As long as controls by the users are concerned, the compact controller F is similar to the conventional type controllers where manual–auto–remote, DC1 to 5V input signal, DC4 to 20mA

output signal, etc. apply. In addition, the compact controller F has a number of superior features such as the employment of plasma display, wafer system program connection, built-in keyboard operator console with LED displays, built-in soft and hard manuals and non-volatile memory. Further, with the combination of the regulating operation and logical judgement, the pulse width and pulse row output function which is one of the Fuji's features is effectively controllable even against motor operated actuators. The compact controller F is especially effective in controlling raw material feeding, mill operation and water valves.

Fig. 5 Instrumentation panel



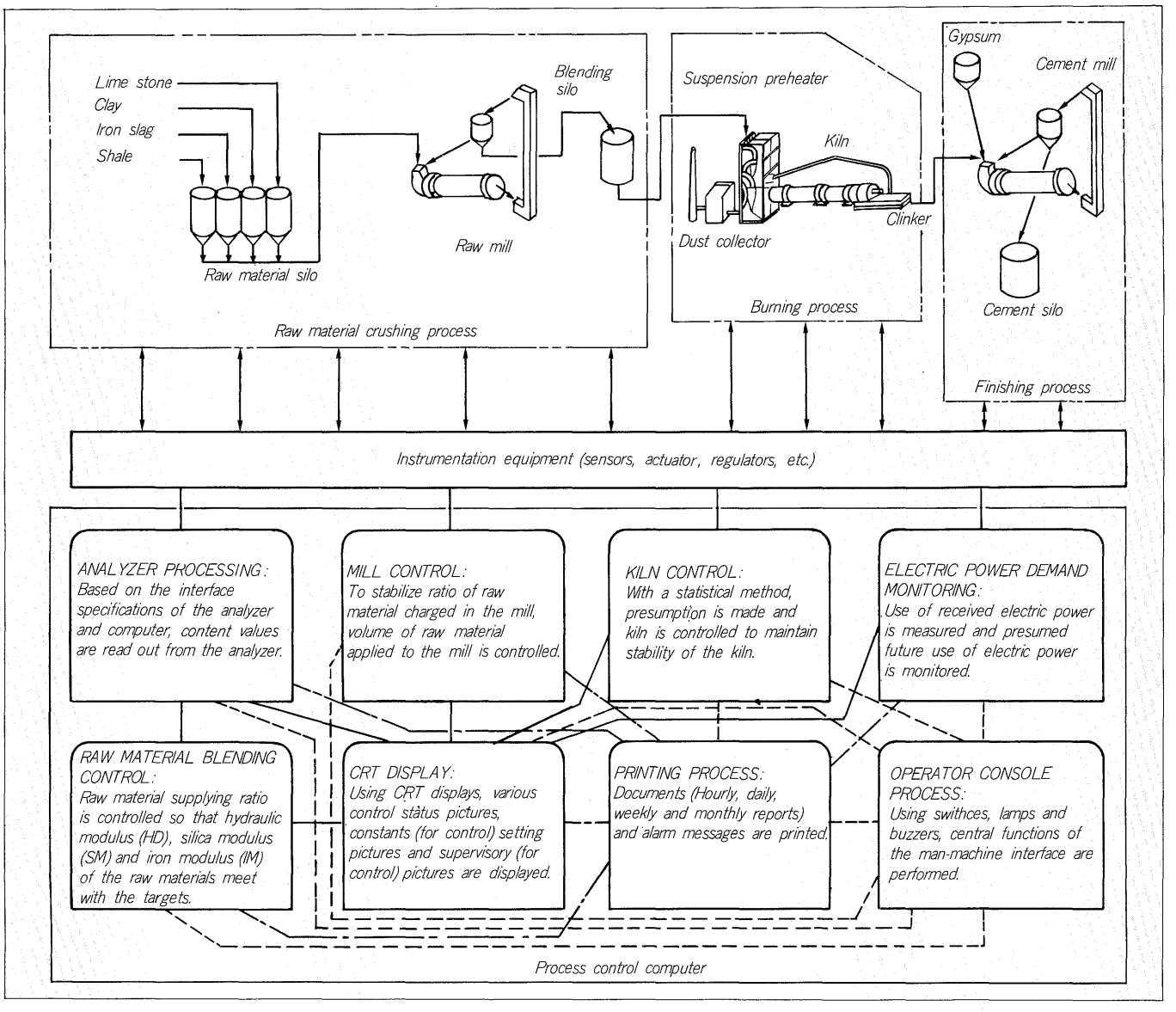
3) CO gas analyzer (infrared type)

This is a non-dispersing type gas analyzer which uses an infrared absorbing method. Employing an IC manufacturing technique applied micro flow sensor, this analyzer is outstanding in the shock resistance, stability and S/N ratio, and the operation and maintenance are easy. This analyzer is used to measure CO concentations in the SP tower, kiln exhaust gas and coal mill.

4) O2 gas analyzer (magnetic force type)

(1) Using magnetic nature of oxygen, this analyzer converts concentration of oxygen to pressure, and

Fig. 6 Contents of computer control



measures ratio of oxygen contained in measured gas.

(2) This analyzer is of a pressure measuring type, and therefore, the response is fast.

(3) Since almost all existing gases are not affected by magnetic field, this analyzer is not affected by any coexisting gases.

(4) The output is linear and DC4 to 20mA outputs can be obtained.

With the above features, this analyzer is used to measure concentration of oxygen contained in SP tower, kiln exhaust gas, etc.

3. Computer

Computers for control are used to compensate the portions which cannot be executed by automatic sequence controller and instrumentation equipment or portions which cannot controlled thoroughly with the automatic sequence controller and instrumentation equipment only so that the optimum control can be attained. At present, almost all newly built cement factories are using computers. The used softwares are for executions of various controls, CRT displays, printing process, data transfer processing with higher level control computers, and with operations of the system engineer and future expansions taken into considerations, easily used softwares are prepared. With processings by the operators taken into considerations, CPU, various peripheral equipment, input/output interface equipment, operator console, simulation equipment, etc. are prepared so that the functions of the prepared softwares can be thoroughly displayed.

1) Contents of computer software

When expressed in correspondence with a cement

Fig. 7 CRT monitor display (electric power demand)

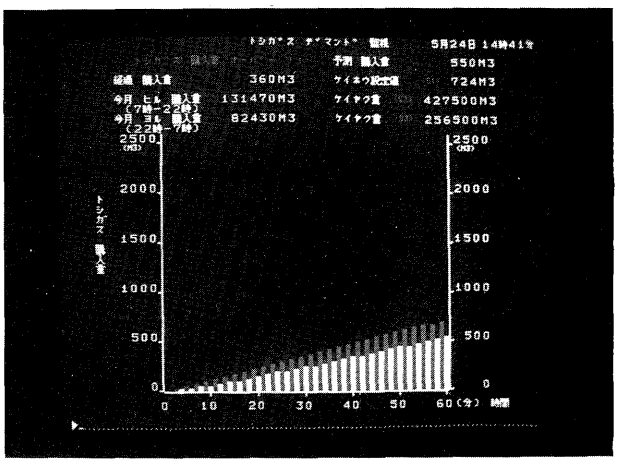


Fig. 8 Hardware composition of computer system

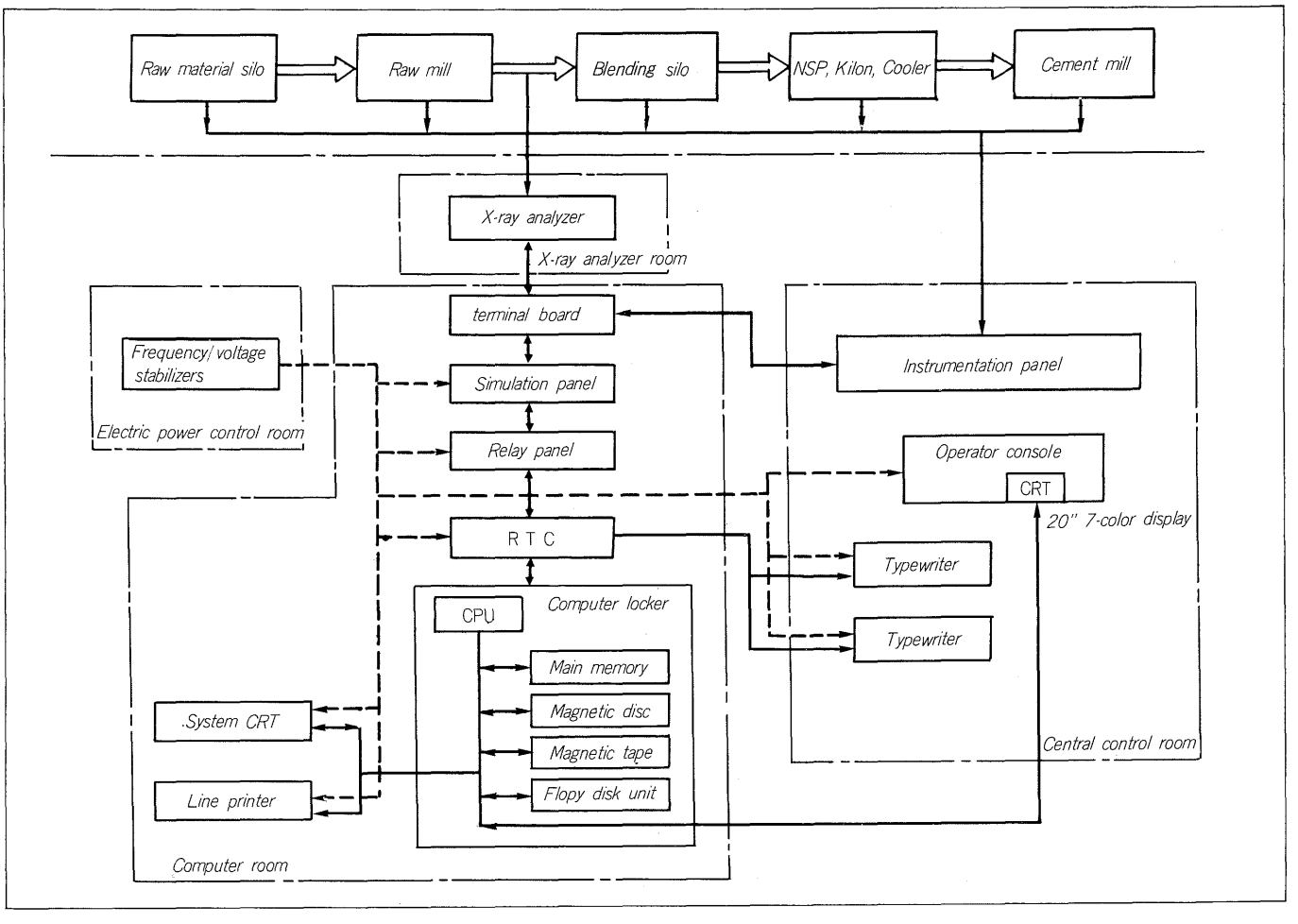
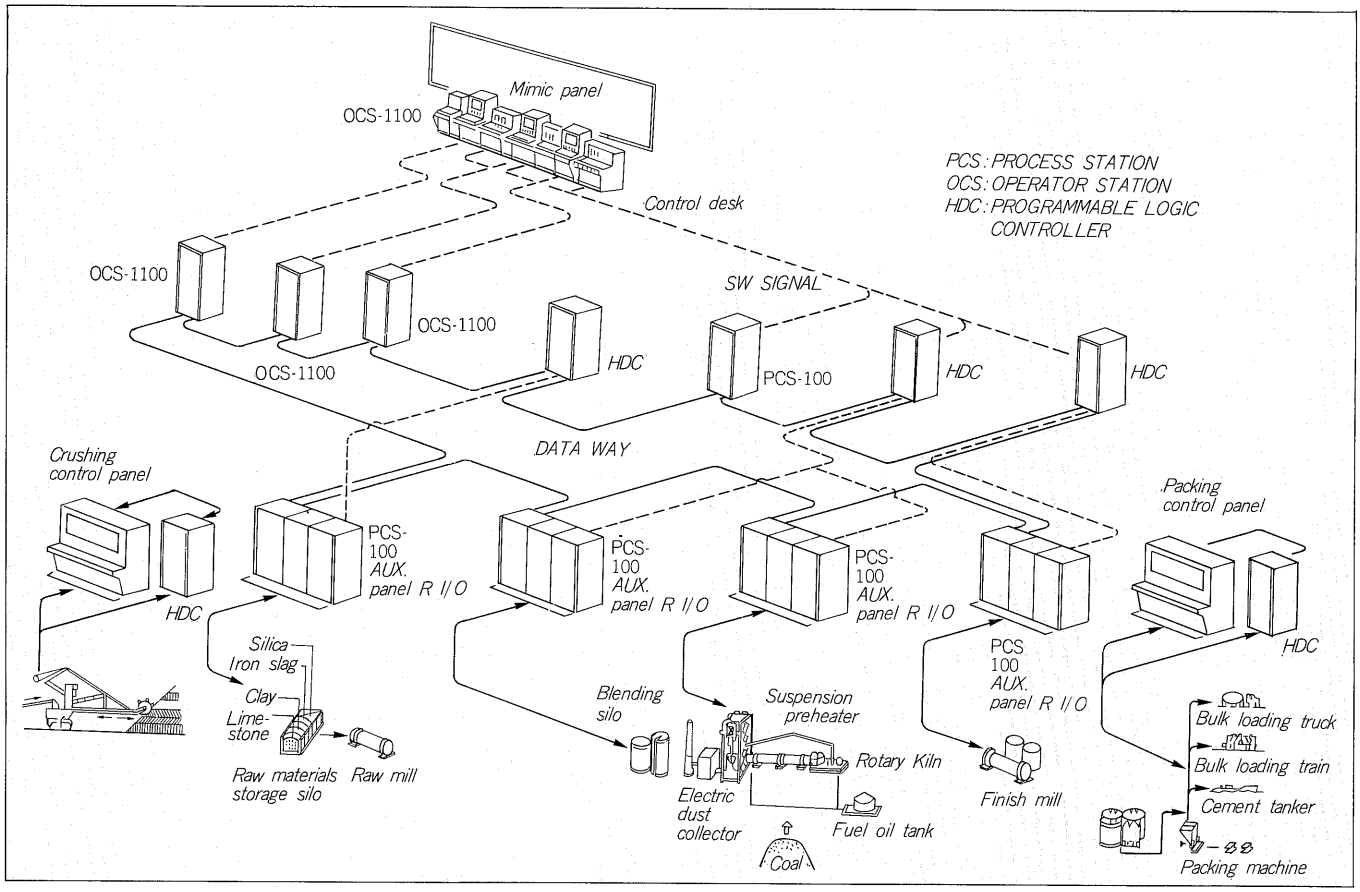


Fig. 9 Overview of DDC system for cement factory



manufacturing process, Fuji's control computer software is capable of covering all the processes from the raw material crushing to the burning and finishing as shown in *Fig. 6*. In this case, the data required for the control are transmitted and received via the instrumentation equipment. The major software functions which can be executed are analyzer processing, raw material blending control, mill control, kiln control, electric power demand monitoring, CRT display, printing processing and operator console processing. Further, applications with the machines and equipment must be noted, and it is also possible to correspond to the product input/output managements.

2) Computer hardware composition

Fig. 8 shows the control computer hardware composition by each unit. In this figure, the full line expresses signal flow, and dotted line expresses electric power supply. Since the most of process status values are concentrated in the instrumentation panel, it is desirable to arrange almost all signal processings and wiring processings for the control computer in a single dimension so that the maintenance can be made conventiently and signals can be transmitted and received via the instrumentation panel. To provide the computer hardware with an adequate and sufficient maintenance service, the simulator panel should be prepared outside the control computer input/output interface equipment so that the hardware can be judged healty or not by the dummy input/output signals generated by the simulation panel without using the actual inputs from the process. For the power supply equipment, it is important to keep the reliability by using M-G type or transister type stabilized frequency/voltage power supply equipment. The stabilized frequency/voltage power supply equipment must guarantee the following outputs.

Output voltage: Within ±3% of the rated voltage (during normal operation)

Output frequency: Within $^{+1\%}_{-2\%}$ of the rated frequency (during normal operation)

4 TREND OF CEMENT FACTORY CONTROLLING TECHNIQUE

1) Movement to distributed DDC system

With backgrounds of the digitalizations of the instrumentation machines and equipment developed during the recent years and improvements of the data transmission technologies, contorl equipment of cement factories are moving to a distributed type DDC system. The distributed DDC system connects the automatic sequence controller using PLC, digital instrumentation system and computer with a data way which functions to transmit a large volume data so that the data can be mutually used among the individual machines and equipment and the factory operations

Table 3 System function distribution

Function \ Device	CRT display	Mimic lamp	CRT keyboard	Desk switch	PCS	PLC	TW
Display for monitoring analogue loop	○						
Analogue loop setting/control	○		○				
Analogue loop control					○		
Analogue loop signal input/output					○		
Analogue loop alarm display	○						
Analogue loop alarm logging	○						○
Motor controlling for supervision and display	○*1	△*1				△*1	
Motor controlling for sequential starting	○		○*2	△*2		△*2	
Motor control						○	
Motor control signal input/output						○	
Motor control alarm display	○*3	△*3				△*3	
Motor control alarm logging	○						○
Data logging	○						○

(Note) *1, *2 and *3 indicate that either ○ or △ can be selected by an operation method.

can be controlled from the operator console located in the central control room.

Fuji's distributed DDC system consists of MICREX series products. The major components are;

(1) Distributed type DDC process station (PCS-100)
(2) High speed programmable controller (HDC-100/200)
(3) Centralized type operator station (OCS-100/1100)
(4) High speed data way (DPCS-E)

Fig. 9 shows the overall system configuration using the MICREX series products. Each system configuration may vary slightly depending on the scale of a plant, idea of the plant operation, redundancy of the system or emergency operability.

Features of this system are that the controllers having calculation control functions are installed separately in the electric control rooms in the plant by each process of raw material crushing, burning and finishing which are dispersely located toward several hundred meters, and that the instrumentation controller and overall controller are joined with the controller having the man-machine interface function located in the central control room through one data way. Thus, composing the system, hazard by each process can be dispersed, maintenanceability is improved, the cable between the site and central control room can be reduced and the construction cost can be greatly reduced. Further, with the same man-machine interface, the instrumentation and overall motor operations can be controlled.

Table 3 shows the equipment which compose the system and functions of each equipment required for the plant operations. Fuji Electric has already delivered the distributed DDC systems using this MICREX series to several cement factories.

5 POST SCRIPT

The recent trend of the cement industries, actual operations and controllers that Fuji Electric has delivered to cement factories during past 10 years were introduced.

To meet with the user's requirements and desires, we will effectively use the electronics technologies which will be further advanced and developed so that we will be able to continuously provide the industries with excellent controllers.