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DEVELOPMENT OF INSTRUMENTATION SYSTEM FOR CONTINUOUS CASTING PROCESS

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1 FOREWORD

The application of continuous casting (CC) to steel works has been amazing and is already used in 90% of the steel production in Japan.

One of the reasons why CC has reached such a high proportion is that the CC process not only saves energy, but is itself a continuous process and is suitable for automation by instrumentation, electricity, and computers. Advancements aimmed at higher production and lower energy consumption are also being made in CC itself. Control system, system configuration, functions distribution, and other CC instrumentation system changes and future trends, together with advances in instrumentation systems are described here.

2 FACILITIES OUTLINE AND ADVANCES

CC is a process by which molten steel is solidified and cut by continuously cooling molten steel blown in a converter and finishing the slabs to the desired size. It was developed for the following three main objectives:

(1) Improvement of productivity and yield by utilizing the features of a continuous process.
(2) Higher quality.
(3) Labor and energy saving.,

3 INSTRUMENTATION SYSTEM ADVANCES

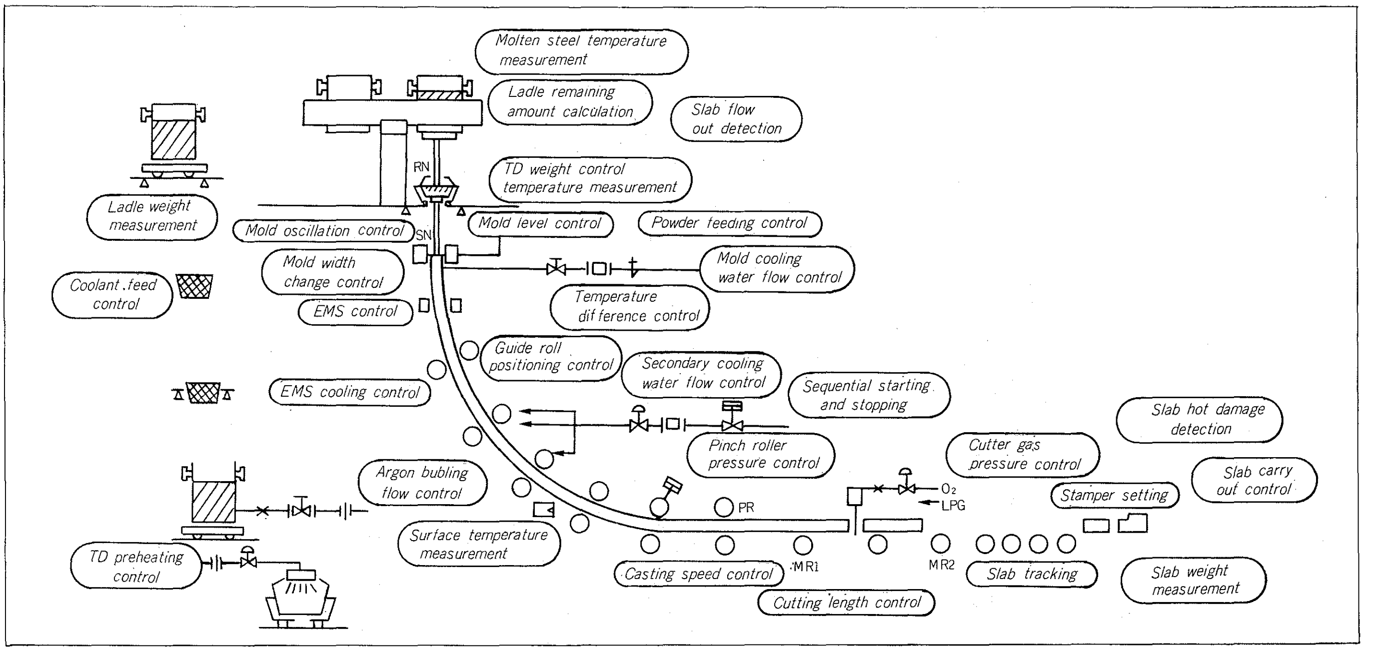
A CC instrumentation system is shown in *Fig. 1.*

1. Sensors and process control

1) Tundish weight control

A load cell is used as the detecting element. A rotating nozzle (RN) and sliding nozzle (SN) are provided as actuators. The primary object of this system is not higher weight control accuracy but reduction of the operating frequency to lengthen the life of the actuators. The large affect the head of the tundish formerly had on the flow-out from the ladle has been reduced by compensation of the gain in mold level

Fig. 1 Instrumentation system for continuous casting process



control. A gate is provided in the tundish to remove inclusives, but control must not assist the flow-out of inclusives whose level changes considerably. P+D band width control has been developed to reduce the operating frequency. Its system is shown in *Fig. 2*.

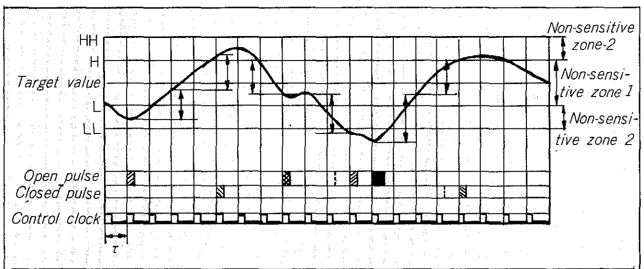
2) Mold level control

The history of the mold level detection methods is shown in *Fig. 3*. Although attempts at development of a large variety of detection elements have been made, three methods are in practical use today: γ-rays, eddy current, and thermocouples.

Recently, there has been a tendency to locate stirring equipment which performs electromagnetic stirring inside the mold, and so forth at the top of the stage. For this reason, electromagnetic induction noise has become a problem which exposes the electrical detection system to noise. Countermeasures against this are under study. Simulation of control methods has been reported many times. However, microcomputerized controllers permit nonlinear compensation PID control, casting speed feed-forward compensation, tundish head compensation, and lost motion compensation of various actuators and also improve control accuracy and stability. SN and stopper are available as actuators and hydraulic and motor are available as drive units.

A simulation configuration using a compact controller is shown in *Fig. 4*.

Fig. 2 2 P + D band control



	Normal output	Force output	Speed response output
	The sample value previously output is made XL. The sample value when threshold value LA is exceeded is made the new XL. (Indicated by ↕.)	The previous sample value is made L_{n-1}, and the present sample value is made L_n.	Same as at left.
Open pulse output condition	Old $X_L > L >$ new X_L or old $X_L > LL >$ new X_L. (Shown by ▨ .)	$L_n \leqq L_{n-1} < LL$ (Shown by ■ .)	$L_{n-1} - L_n > L_A$ and, $L_n < H$ (Shown by ▩ .)
Closed pulse output condition	Old $X_L < H <$ new X_L or old $X_L < HH <$ new X_L (Shown by ▧ .)	$L_n \geqq L_{n-1} > HH$	$L_n - L_{n-1} > L_A$ and $L_n > L$

Fig. 3 History of mold level sensor

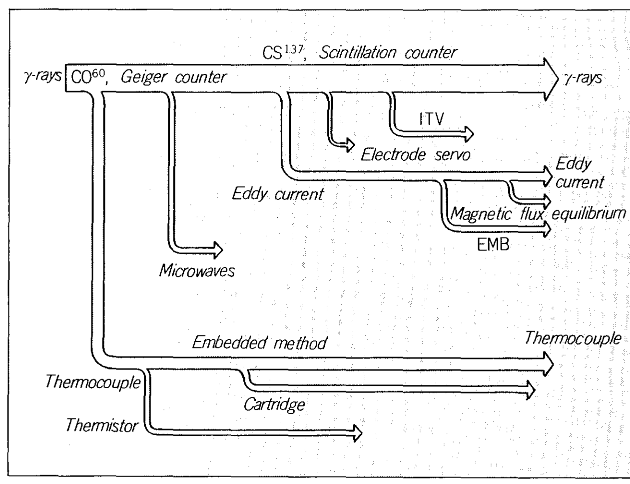


Fig. 4 Simulation flow diagram using CC-F

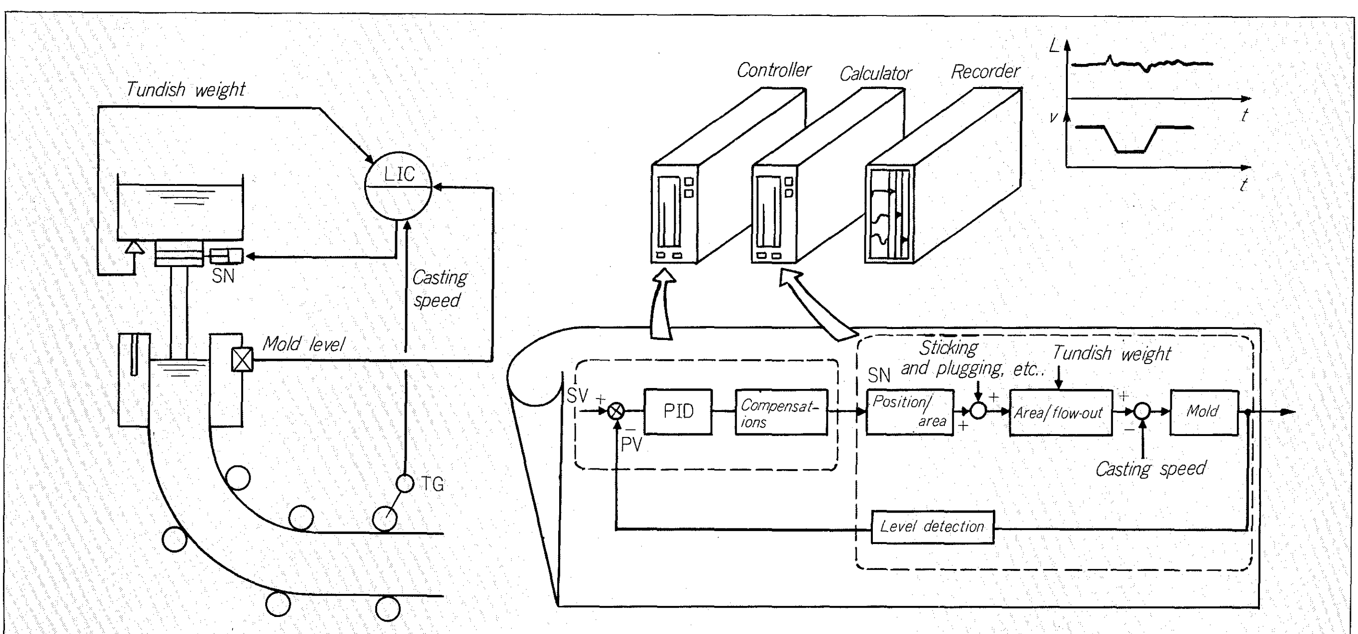


Fig. 5 Flow control block diagram

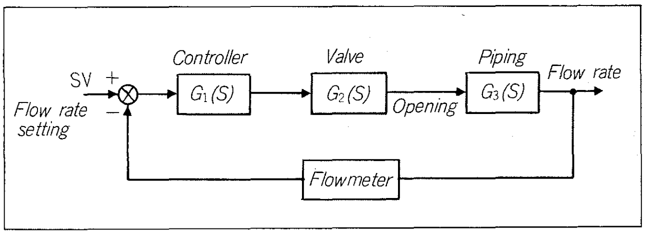


Fig. 6 Simulation control result

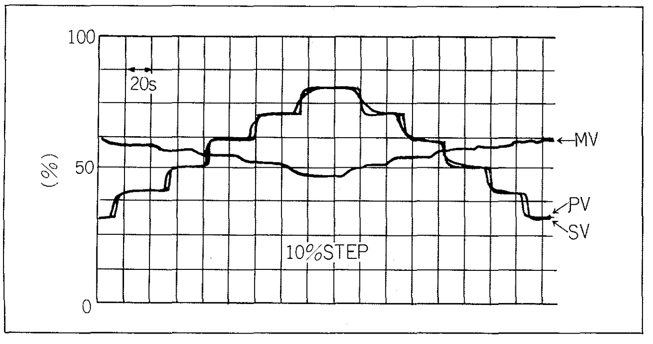
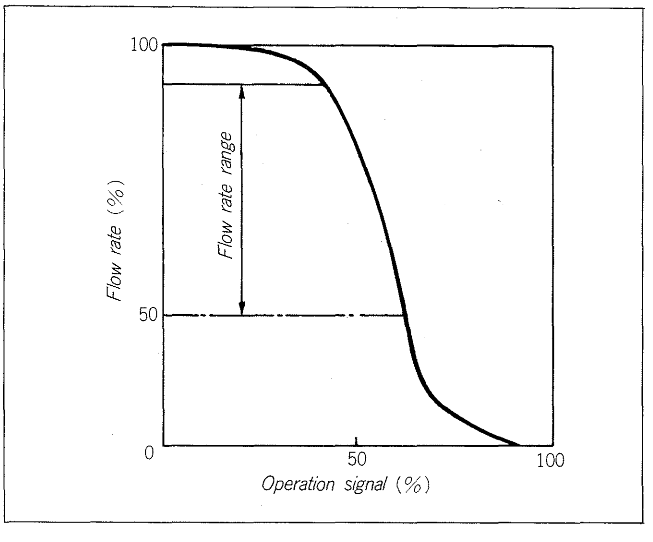


Fig. 7 Flow characteristic of valve



Fuji Electric Co., Ltd. offers the following as simulation tools for various process control:

(1) Business computer

(2) Analog computer

(3) Compact controller + calculator

and deal with process control, from modern to classical. A CAD system has been developed. Bode diagrams, transient response curves, and so forth can be easily drawn on a CRT.

3) Secondary cooling water flow rate control

(1) Detector and actuator

An electromagnetic flowmeter is used as the detector. As the actuator, many globe valves have been replaced by eccentric rotary valves which have a wider flow control range.

However, when such devices are used, the stability of the entire system, including the characteristics of the nozzle, pump, and piping, must be checked. The flow control block diagram is shown in *Fig. 5.* An example of simulation by compact controller of an eccentric rotary valve offered by a certain manufacturer is shown in *Fig. 6.* The flow characteristic of a valve calculated from the valve CV characteristic and piping characteristic is shown in *Fig. 7.* The CV characteristic of the valve is given by using a linearizer.

(2) Flow rate setting control

Control is divided into the methods shown in *Fig. 8.* In each method, since the parameters vary with the steel grade and size, the joining parts when different steels are continuously cast are tracked and the parameters must be successively changed.

Because specific water setting control essentially ignores the past casting state, that is, the casting speed, solidification thickness, etc., and determines only the present casting speed, depending on the kind of steel, it suffers from internal defects such as center segregation due to the unsolidified portion left in some kinds of steel.

Control with numerical models is desirable for unstable conditions. If the surface temperature at the bending point of some steels is not precisely controlled, many cracks will be produced, etc. and the setting method must be changed according to the kind of steel and machine design.

(3) Other control

Other control methods include overcooling compensa-

Fig. 8 Kinds of 2nd cooling water flow rate set point control

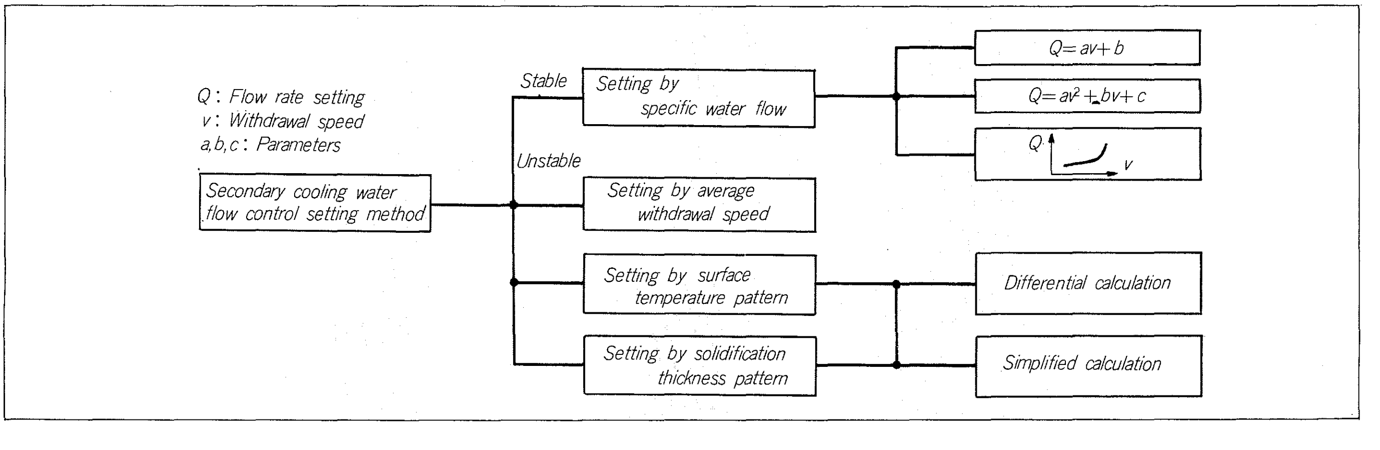


Fig. 9 Trends of distribution control system

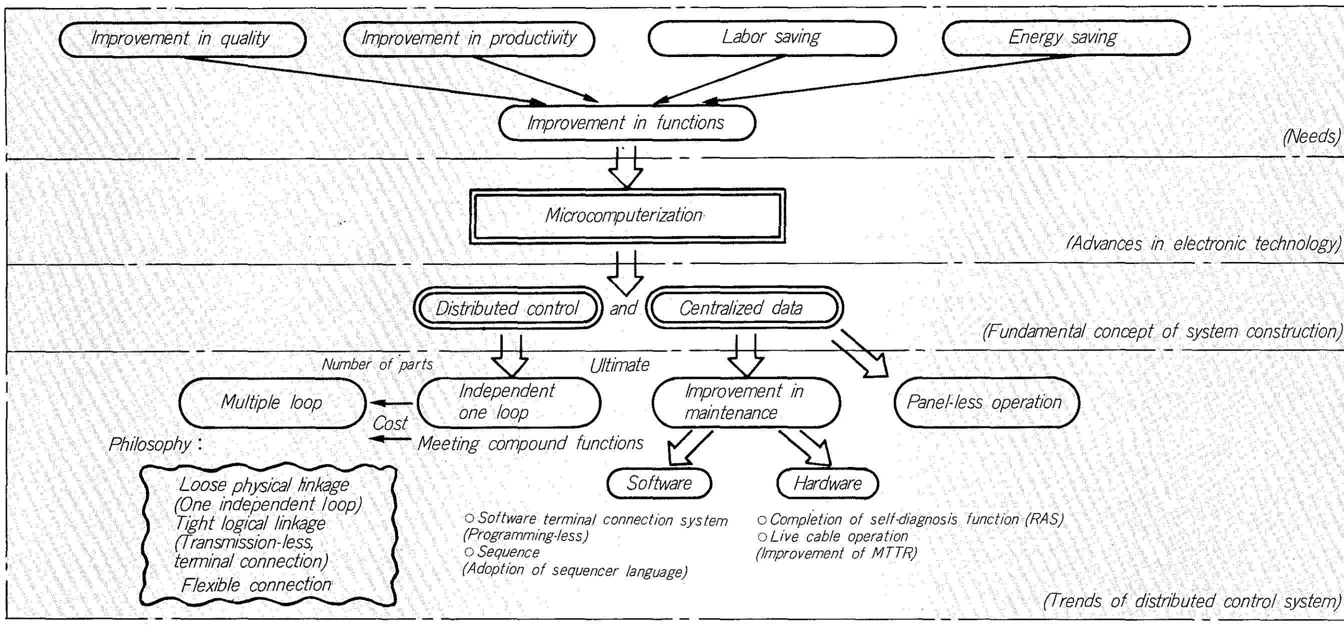
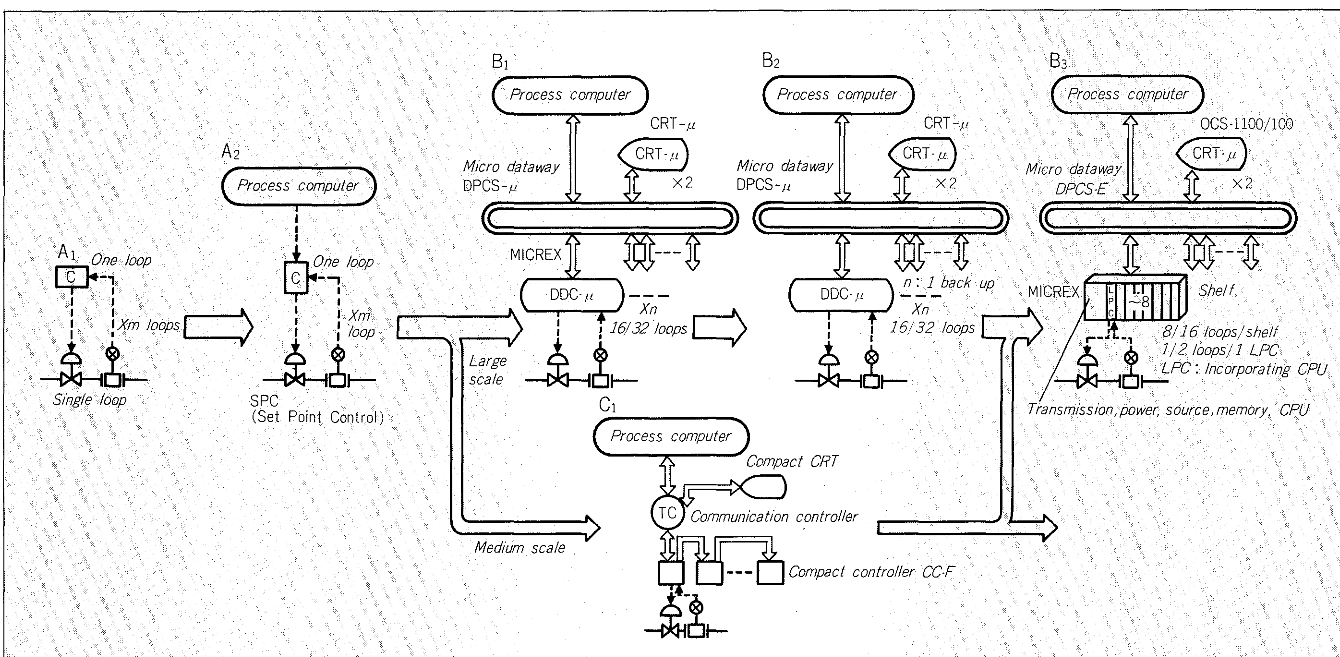


Fig. 10 History of continuous casting instrumentation control system



System / Comparison items	Analog control		Digital control (multiple loop)			Digital control (single loop)
	A1	A2	B1	B2	B3	C1
System construction	① Analog controller ② Analog arithmetic unit	① Computer setting analog control ② Analog arithmetic unit	① MICREX-P/W ② CRT-μ ③ Backup setter	① MICREX-P/W ② CRT-μ ③ Backup setter ④ n : 1 backup DDC-μ	① MICREX shelf construction ② OCS-1100/100	① Compact controller (CC-F) ② Communication controller ③ Compact CRT
Features	——	Optimum setting by computer	○ Complicated control ○ Centralized management/ distributed risk	○ Same as at left. ○ Reliability	○ Serviceability ○ Panel-less operation ○ Ultimate distribution ○ Harmony of DDC and sequence ○ Cost	○ Simple construction (Best for medium and small systems)
Problems	○ Incapable of complicated control ○ Incapable of modification for steels by tracking ○ Large panel area	○ Same as at left.	○ Reliability ○ Cost ○ Manual 16/32 loop operation at breakdown	○ Cost ○ Serviceability of software	——	○ Limited functions ○ Small parameter file ○ Low memory capacity

tion by tracking the overcooled part of the slab and sequentially changing the water flow setting, specified opening control which governs the water flow rate when the power fails, intermittent control at initial flow rate setting and flow rate setting below the nozzle characteristic, etc. Air-water spray cooling can reduce nozzle clogging. Clogging is detected by calculating the nozzle backpressure.

2. System construction

Microcomputer advances have changed the form of system construction and the system advances are likely to be made on the basic concept of distribution of control and centralization of data as shown in *Fig. 9*. The trend of distributed control is thought to be toward independent control in single-loop units, but can change according to the operation method of the plant, etc. In the case of air-water spray cooling, for example, the minimum unit is two loops: water and air.

The logical linkage between DDCs and between sequence and DDC must be suitably tight and must expand as virtual space.

Moreover, data must be freely and easily linked to units including a process computer or CRT centralized monitor equipment in the system, if any. In short, a form with loose physical linkage (trouble is restricted to certain points and does not extend to others) but tight logical linkage will be the trend of future distributed systems. The history of system construction is shown in *Fig. 10*.

4 FUNCTION SHARING

With the improvement of microcomputer performance, microcomputers can perform some processing within the range of processing computers. However, in the present stage, process computers are superior to microcomputers from the standpoint of software maintenance because of the better performance of peripheral devices such as CRT and high speed printers.

Therefore, processes with unestablished software logic, processes under development, and processes requiring the handling of a large volume of data should be handled with a process computer. Microcomputer are also not suitable for tuning and refining of models and the accumulation of analysis data. However, there is no objection to the use of a microcomputer to process the functions to be processed when the process computer breaks down. In this case also, the process should be as simple as possible and sufficient consideration should be given to maintenance and operator input frequency and amount and output system.

5 RELIABILITY

The concept of distributed risk for CC distributes the process among minimum strand units, but halting of one strand by microcomputer failure still a problem. When a failure occurs at a multiple-loop controller, manual backup by the operator is not practical whether there are 8 or 16 loops. Therefore, the ultimate distributed unit should be one loop. However, sequence control, tracking, parameters file, and so forth are common to conventional systems and cannot be distributed.

Therefore, instrumentation should be loosely coupled physically (one independent loop) but tightly coupled logically (transmission-less).

Some parts must be duplexed, but is necessarily costly, and the recovery method, maintenance, and so forth must be amply studied.

6 MAINTENANCE

Maintenance of both software and hardware must be considered as one data centralization method. Therefore, as a rule, it should be possible to perform all maintenance on a CRT.

The compact controller (CC-F) and MICREX DDC software employs a wafer connection system. Its features are continuous work which can shift from the instrumentation block diagram used for functional design to wafer connection diagram and easy maintenance.

Maintenance of live cable has also become essential. The trouble diagnosis function for detecting card faults is being increasingly enhanced and classification of this function has been attempted.

7 PANEL-LESS OPERATION

With the conventional multiple-loop controller, a backup setter with indicators is provided as a countermeasure against breakdowns. Therefore, a panel was necessary. However, a minimum of one loop like with the MICREX eliminates the need for a panel. The CRT becomes the center of the man-machine interfaces, and it is usually duplexed to avoid blind control.

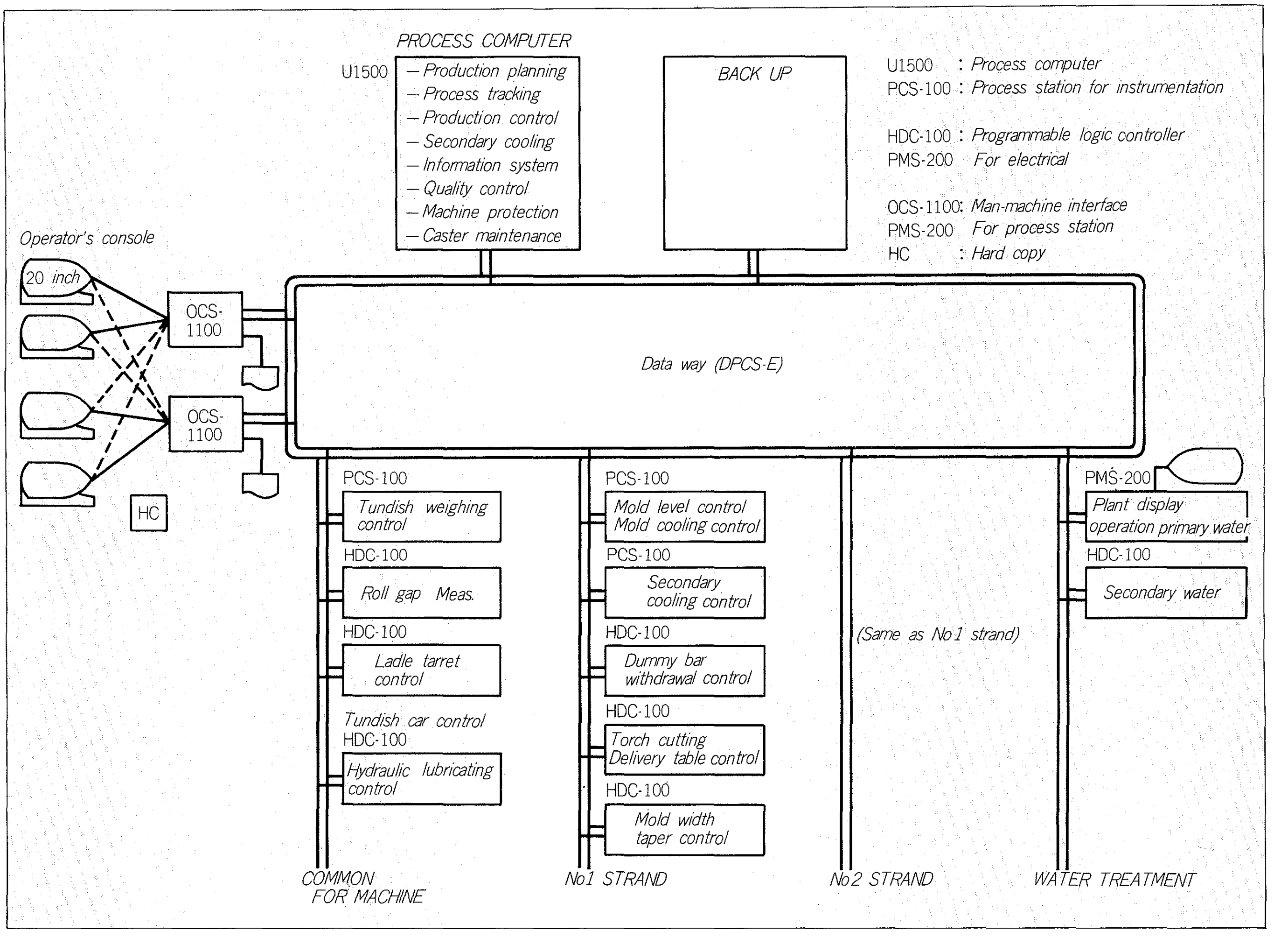
Recently, standard CRT pictures alone has become insufficient and the pictures are determined by studying what information is truly needed by the operator. For this reason, the OCS1100/OCS-100 has an interactive screen generation function which allows the operator to create the necessary pictures. Voice service has also become more minute. However, alarms for serious faults should be given by hardware detection and hardware indication.

8 EXAMPLES OF DISTRIBUTED SYSTEM CONSTRUCTION

An example of the system construction of a distributed control system which integrates the electric, instrumentation, and computing functions is shown in *Fig. 11*. A feature of this system construction example is that since for the interfaces between electric, instrumentation, and computer is used a dataway and the PIO unit of the process computer is shared by the electric and instrumentation process station, costs are reduced substantially. Other features of this example are:

(1) Sharing of man-machine interface

Fig. 11 System configuration



(2) Reduced work expenses
(3) Fast transmission
(4) Exapndability and extendability
(5) High reliability

9 CONCLUSION

It has been almost six years since digital control was applied to CC equipment. During this time, most of the theoretically possible things have been realized. In the future, a strong demand will rise for integrated systems from the viewpoints of cost, reliability, and serviceability versus system construction. Practicalization of facility diagnosis technology and automation of maintenance are desired.