Abridged version

KAWASAKI STEEL TECHNICAL REPORT
No.5 (May 1982)

Automatic Control of Chiba No.3 Continuous Casting Plant

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Synopsis :
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Automatic Control of Chiba No. 3 Continuous Casting Plant*

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Full automatic operation of continuous casting contributes greatly to attaining a high product quality, a stabilized operation and a high slab productivity.

This paper outlines a virtually full automatic control system developed at No. 3 CCM of Chiba Works, and a variety of related technologies including the following:

(1) Width change during high speed casting
(2) Start-finish control of casting
(3) Computerized slab handling crane
(4) Quality assurance system

1 Introduction

Full automatic operation of continuous casting plant is effective not only for the labor saving and the stabilization of product quality and operation. But it also contributes to the improvement of working surroundings and safety level. Accordingly, each steel manufacturer has been making considerable efforts in automatization, with the results[1] reported from time to time. The achievement, however, is limited to various processing zones, falling short of full-range automatization covering from ladle teeming, casting, slab handling crane operation, including non-regular operation for starting and ending of one strand.

In the automatization efforts of continuous casting, what generally comes as the main bottleneck is the so-called non-regular work requiring manual operation of skilled workers, such as casting start, tundish change and slab width change during casting. Moreover, the need for energy saving has highlighted a growing tendency toward transferring hot slabs to the subsequent (reheating) process bypassing conditioning.

This calls for the improvement of working environments for slab yard crane operators in their handling of hot slabs. In addition, from the need of establishing a secure material handling management system, a computer-aided automatization of crane operation becomes necessary.

This report describes No. 3 CC plant, with emphasis on its full automatization attained by the application of other automated facilities developed earlier by Kawasaki Steel and by some additional developments.

2 Outline of Automatization Aimed

The automatization of various units of equipment was established aiming the following:

(1) Automatization throughout the whole process from ladle bubbling to slab handling.
(2) Automatization of non-regular work such as at casting start and casting end as well as tundish change, so as to permit a full automation operation beginning with a button-pushing for starting ladle pouring.
(3) Automatization of slab handling crane, so as to attain automated slab inventory control system and material handling management system.

2.1 Computer System

The computer system at No. 3 CC plant, as shown in **Fig. 1**, consists of three computers, namely, microcomputer (hereinafter abbreviated as μ/C), process control computer P/C) and a line computer (L/C) which supervises the production control of the entire iron mill.

These computers are organically connected in order

* Originally published in *Kawasaki Steel Giho*, 14 (1982) 1, pp. 20–27
** Chiba Works

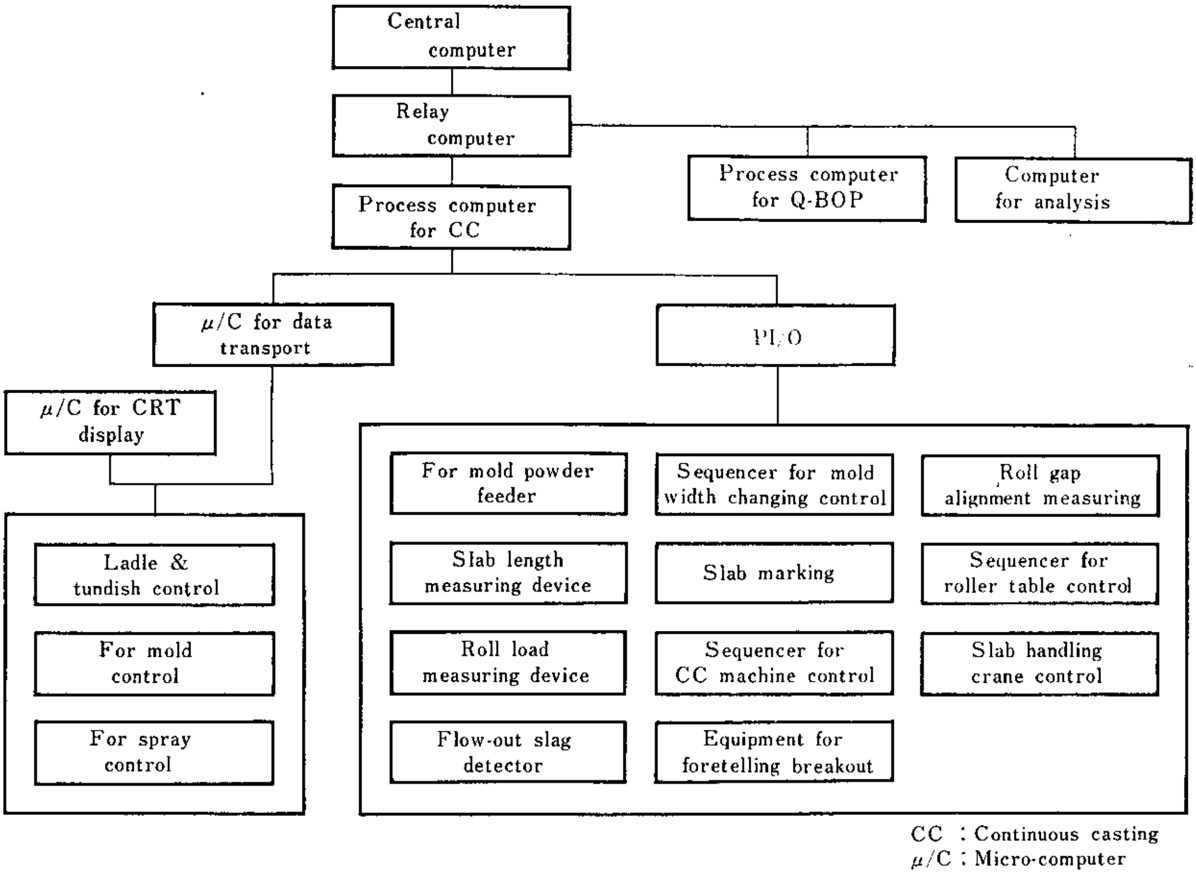


Fig. 1 Schematic diagram of computer control system at No. 3 CCM

to carry out a wide range of automatic control and data collection covering from mold powder feed control to slab handling crane.

2.2 Items of Automatization

Molten steel coming from the bottom-blown converter is mainly treated by gas bubbling, though partially treated by RH degassing. The items of automatization in bubbling processing are given in **Table 1.** The amount of Al wire input is automatically computed by not only temperature measurement and sampling but also the oxygen measurement of molten steel in the ladle, so as to permit a stabilized deoxidation adjustment. As for Al wire input, especially, the drum system, which had been problematical, was changed to the loose coil system, as shown in **Fig. 2.**

The items of automatization of a continuous casting machine operation are given in **Table 2.** For an unmanned operation of the whole process from the start of ladle pouring on down, an unprecedented scale of automatization has been realized including automatic on/off system for cable and gas pipe for the ladle sliding nozzle, mold powder charging system well suited to its consumption distribution, non-regular work such as pouring preparation and tundish change,

Table 1 Automated items for molten steel treatment

1	Sampling
2	Temperature measurement
3	Remote connection/disconnection of bubbling gas pipe
4	Al-wire feeding control by dissolved oxygen measurement

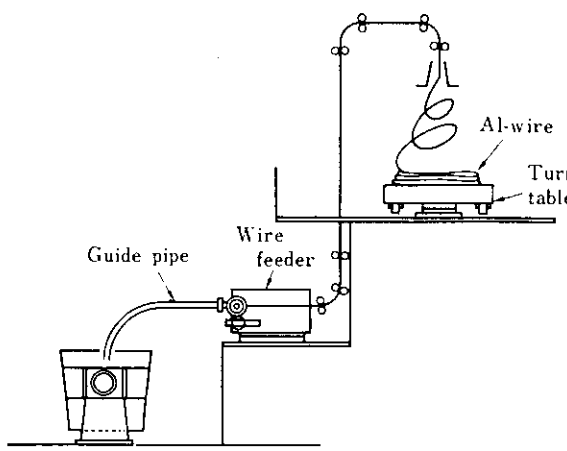


Fig. 2 An outline of Al-wire feeding system in Chiba No. 3 CCM

Table 2 Automated items in continuous casting

1	Gas bubbling on the swing tower
2	Connection/disconnection of pipes and electric cables between ladle and swing tower
3	Tundish preheating
4	Exchange of tundish car
5	Mold powder feeder
6	Long nozzle setting and slag detector
7	Steel bath level control in tundish
8	Slab width change during casting
9	Casting start and stop
10	Steel bath level control in mold
11	Slab surface temperature control
12	Pressure control of secondary cooling water
13	Hydraulical pressure control on pinch roller
14	Breakout prediction system
15	Tension free strand casting
16	Roll gap presetting
17	Mold taper control during casting

Table 3 Items for slab handling and slab conditioning

1	Slab cutting
2	Table roller control for slab handling and piling
3	Slab marking
4	Torch cut slag removal
5	Slab handling by slab yard crane
6	Warm scarfing machine for fin free slab

Table 4 Items in machine maintenance

1	Roll gap measuring and data logging
2	Spray nozzle check
3	Roll load measuring
4	Various data logging of operation

and mold width changing unit for a speedy slab width change during casting.

The items of automatization concerning slab handling and slab conditioning are shown in **Table 3**. As described in another report[2], No. 3 CC plant has a layout which emphasizes the sending of hot slabs, together with such devices as the slab marking equipment developed by Kawasaki Steel, torch cut slag removing equipment, etc. all necessary for the sending of hot slab. These devices are connected with P/C for the sake of automatization.

The items of automatization concerning maintenance are shown in **Table 4**. The subject of automatization efforts aimed to establish a system which serves for a speedy furnishing of a guide to operation and maintenance through the computerized filing of past data on CC machines, and data processing using P/C on roll gap and roll alignment measurements, and hydraulic oil control.

The stabilized operation of No. 3 CC plant is attributable to a satisfactory operation of the abovementioned various units of automatic equipment.

3 Principal Automatic Equipment

Among automatization items at No. 3 CC plant, the devices for mold width change during casting as well as between casting and casting, automatic casting system, hot slab handling crane and the automatization for quality assurance will be outlined in the following.

3.1 Automatization of Mold Width Change

Recently, the casting capacity of CC machine has markedly been improved by the development[3] of the technique for slab width change during casting. This technique is effective for continuous casting of slabs of different widths. It can continuously change strand width from large to small or the other way around in order to make the CC operation fit in with the timing of hot rolling schedule thereby attaining a continuation of continuous hot rolling.

In continuous slab casting, on the other hand, slab width tends to narrow at the start and the end of the casting, or at the time of an extremely slow speed casting, resulting in insufficient coil widths. As a countermeasure for this weak point, the subject device works effectively in controlling the slab width during casting so as to prevent the insufficient width.

The control system for mold width change is shown in **Fig. 3**. The device is an improvement over earlier techniques developed by Kawasaki Steel. Major points are as follows:

(1) Vertical surface control of mold narrow side
The narrow side of the mold is so designed that the angle of its face that contacts the edges of a slab strand being cast can be adjusted vertically to keep the best possible contact. Also, heat extraction at narrow side during width change is as good as in regular operation even the narrow side is moving at high speed.

(2) Installation of narrow side support roll
In order to prevent bulging in the lower section of the mold narrow side during a high casting speed, a narrow side support roll is provided so as to come in proper contact with the strand slab any time even during width change.

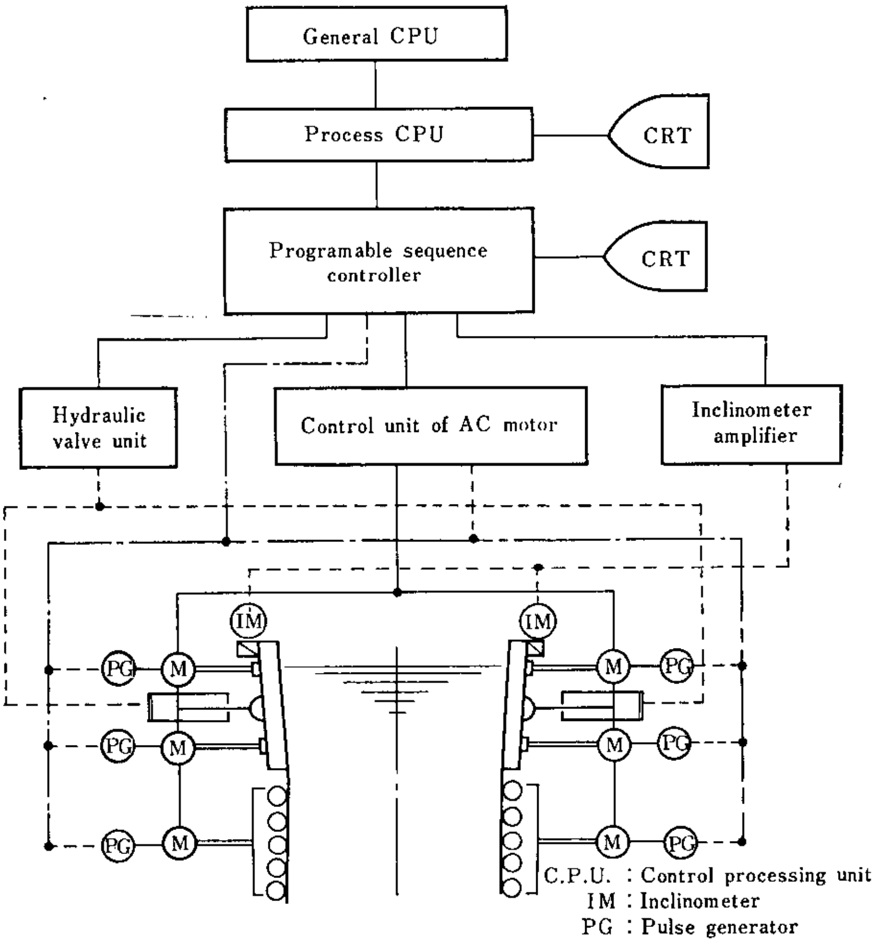


Fig. 3 Principal configuration of slab width change

Table 5 An example of slab width change data during casting

Slab width change	From 1 300 mm to 1 260 mm
Mold taper	1.1%/m (constant)
Ratio of shrinkage	1.4%
Casting speed	1.4 m/min
Narrow face drive speed	6 mm/min
Taper control during casting	Required

(3) Full automatic width change system

Various kinds of operational data such as the amount of width change, the timing at casting start or end, the method of mold narrow side position control, etc. are inputted in advance into the sequencer from P/C in order to carry out width change full-automatically.

A practical example of slab width change during casting is shown in **Table 5**. The use of mold narrow side position control has made possible the high-speed width change during a high casting operation. This system is now routinely operated.

3.2 Full Automatic Casting System

The automatization of ladle pouring, and the teeming from tundish into a mold at the time of regular casting has already been established. However, a full automatization including non-regular work such as at the beginning of casting remains one of the most difficult tasks, and this has not been attained as yet.

For the construction of the subject CC plant, the automatic casting system as described in the following was developed, aiming at a system in which subsequent operation can be automatically carried out by pressing a button for ladle pouring start. By the development of this system, the slab quality in non-regular operation period and the CC operation itself have been stabilized.

The key point of this system is, as shown in **Fig. 4**, a control system consisting mainly of μ/C and P/C. Automatization has been established on various control systems as shown in **Table 6** by combining the existing techniques with new techniques developed by Kawasaki Steel. At the time of casting start in continuous casting operation, the teeming of molten steel

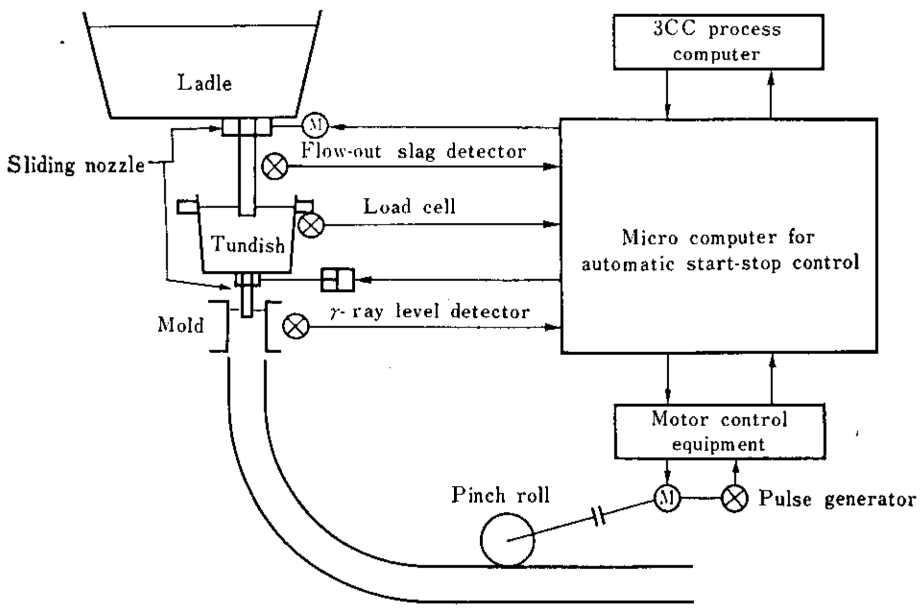


Fig. 4 Configuration of automatic start-finish control system

Table 6 Control items in full automatic control system

○ Developed in the past
◎ Developed this time

Items	Dynamic condition (casting start)	In steady state	Dynamic condition (ladle exchange)	Static condition	Static condition	Dynamic condition (tundish exchange)	Static condition	Static condition	Dynamic condition (casting end)
Closing of ladle sliding gate(Slag detector)			○						○
Steel bath level control in tundish	○	○	○	○	○		○	○	
Closing of ladle sliding gate						◎			◎
Programed bath level rising control in mold	◎					◎			
Steel bath level control in mold		○	○	○	○		○	○	
Start of withdrawal	◎					◎			
Acceleration and deceleration of withdrawal speed	○					◎			◎
Stop of withdrawal						◎			◎
Withdrawal speed control		○	○	○	○		○	○	
	← 1st charge →		········		← *m*th charge →		········	← Last charge →	

and the extraction of strand slab should be carried out while forming solidified shell having sufficient strength without such troubles as the blockage of the tundish sliding nozzle, steel leakage from mold and dummy bar, breakout, overflow, etc.

Therefore, the most essential point is how to control the surfacing speed of the molten steel level in the mold. In this system, since the level of the molten steel in the mold can be calculated by the difference between the amount of molten steel poured from tundish and the amount of strand slab extracted from the mold. The rising speed of the molten steel level in the mold is given as aimed and the opening control of the tundish sliding nozzle is controlled using the following equation.

$$A=\frac{S\rho_s}{\alpha\rho_l\sqrt{2gh}}\left(\frac{\rho_l}{\rho_s}L+V\right) \quad \cdots\cdots\cdots\cdots\cdots(1)$$

A: Opening area of tundish sliding nozzle
S: Mold cross section
ρ_s: Density of strand slab
ρ_l: Density of molten steel
α: Flow coefficient
g: Gravitational acceleration
h: Molten steel head in tundish
L: Molten level rising speed in the mold
V: Casting speed

Thus, casting speed V is controlled at 0 from the pouring start of tundish into the mold to the start of pinch roll drive, whereupon the above equation is applied until casting speed reaches the regular level.

At the casting end, on the other hand, slag involvement is caused by the reduction of the molten steel level in the tundish, leading to slag inclusion, thereby markedly deteriorating the strand quality. In order to prevent this slag inclusion, the casting speed is controlled, and automatically stopped when necessary, in accordance with the change of the molten steel level in the tundish at the end of casting. A practical example of these automatic start and stop is shown in **Fig. 5**.

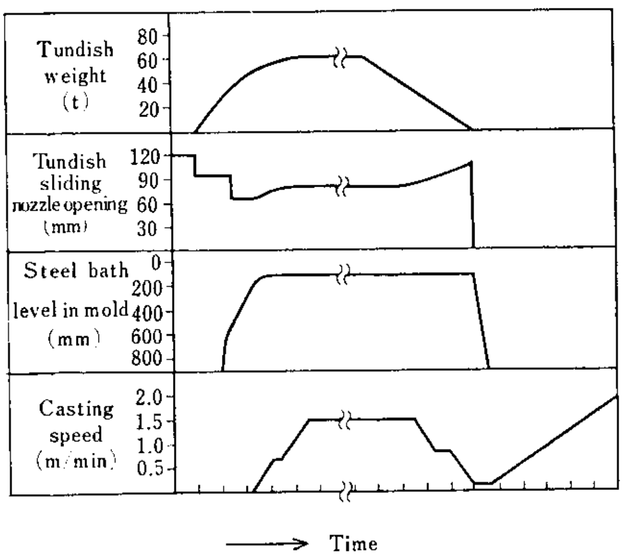


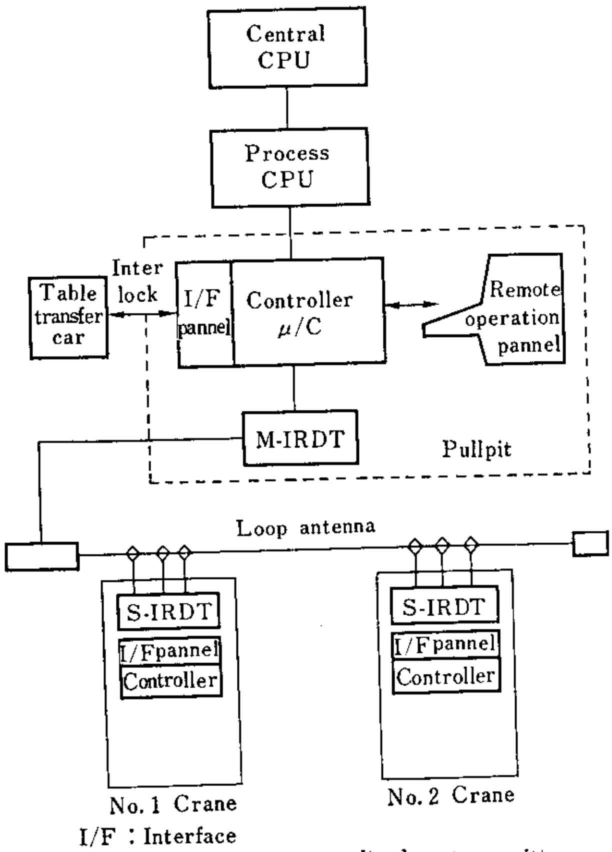
Fig. 5 An example of automatic start-finish result

This system is utilized in the work of tundish change during casting, and thus the full automatization of casting work has been attained.

3.3 Automatization of Slab Handling Crane

In order to establish the labor saving of crane operation and the improvement of working environment as well as the material flow control and the stock control by the slab address control in the yard, unmanned operation of two slab handling cranes was carried out by the following specifications:

(1) Crane Type: Mast type overhead travelling crane with 80 t slab lifter
(2) Number of cranes: 2
(3) Detection of running and traversing positions: Synchro-resolver
(4) Stoppage accuracy: Running ±33 mm
Traverse ±13 mm



I/F : Interface
M-IRDT : Master inductive radio data transmitter
S-IRDT : Slave inductive radio data transmitter

Fig. 6 Configuration of automatic slab handling crane control system

(5) Radio control system: Inductive Radio Data Transfer System (IRDT)

Above all, this crane automatically controls its positions and speeds in its running, traversing and slab lifting up. It requires complex movements such as slab handling to and flown a predetermined address in the slab yard. Moreover, it carries out complex control such as the selection of job instructions for two cranes.

The systematic diagram of this crane is shown in **Fig. 6**. The job instructions to each crane from the line computer are transmitted to the controller on the crane by the induction radio system via the controller installed on the ground, and the cranes executes the job automatically. The job result is transmitted to the process computer through the inverse route, and it is transmitted from the process computer to the line computer.

The line computer recognizes every information slabs in the slab yard and carries out slab stock control and material flow control by instructing effective operations of the crane.

As a means of backing up computer troubles, this crane is so designed as to be operable by a semi-automatic mode for automatic operation from a remote panel on the ground, and also by a manual operation mode from the crane.

3.4 Automatization for Quality Assurance

3.4.1 Automatic detection of abnormal strand

For various operational factors which exert detrimental influence upon the quality of cast strand such as the sudden change of the molten steel level in the mold, a system which automatically identifies corresponding slabs (abnormal cast pieces) is provided to carry out the control of abnormal cast pieces. Especially, in order to automatically detect the abnormalities of operation, an automatic detecting function as shown in **Table 7** has been developed.

Table 7 Automatic rejecting system

Items	Note
1) Slag contaminations from the tundish	Tundish weight variation
2) Insufficient shrouding from ladle to tundish	N pick up between ladle and tundish
3) Hanching of steel bath level in mold during casting	Level variation
4) Detection of momentary cast stop	Strand stoppage
5) Out of range in chemical composition	

3.4.2 Roll gap and alignment measurement

Roll gap and alignment measurement is practiced before the start of each casting by an equipment provided on the dummy bar. Its data is directly fed to the process computer, and the operation and maintenance guides are worked into the data which can easily be understood by the operator.

An example of the result of roll gap measurement is shown in **Fig. 7**.

3.4.3 Detection of torch cut slag removal

Since torch cut slag causes defective product surface, a removing equipment is provided. For an energy detection of a trouble of the plant and for the sake of quality assurance for the subsequent process, a slag removal detecting equipment, as shown in **Fig. 8**, is provided.

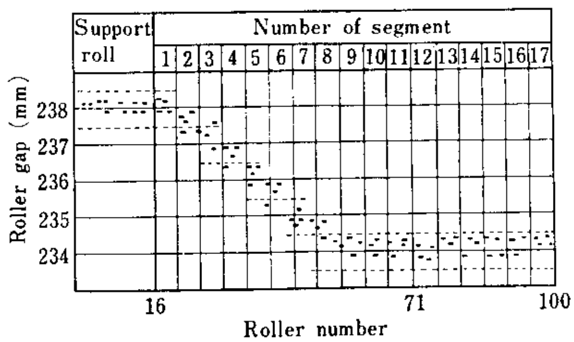


Fig. 7 Record of roller gap measurement

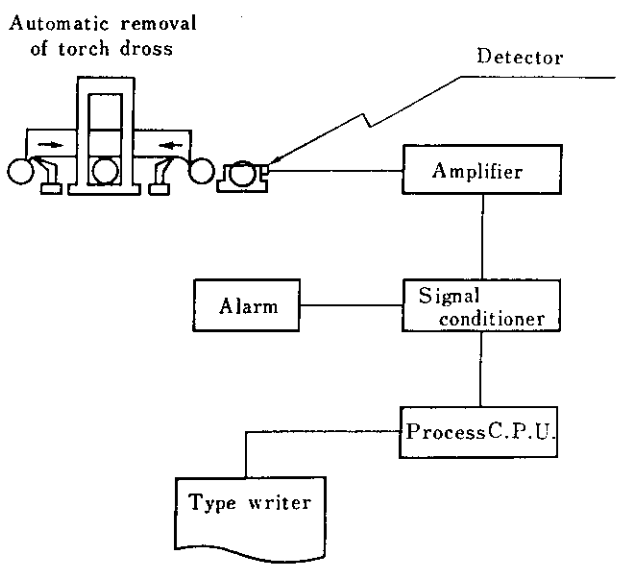


Fig. 8 Configuration of torch cut dross detection

4 Conclusion

In the No. 3 CC plant the full automatization from ladle pouring to slab handling has been attained by the installation of the automatized equipment developed by Kawasaki Steel in the past and newly.

In particular, many effects such as the improvement of the cast strand quality in non-regular portions, the stabilization of operation, etc. have been obtained by the automatization of non-regular works.

In the future, a hot slab defect detecting equipment is to be developed and a total labor saving including maintenance will further be pursued.

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