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The body can be viewed from the next page.

Automatization of Manual Operations in the Continuous Casting Process*


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1 Introduction

Along with the rise of continuous casting ratio, the reinforcement and rationalization of equipment aimed at the stabilization of operation and slab quality have been put forward. Up to the present, the automatization of main operations such as changing slab widths during casting, controls of molten steel in the tundish, casting speed, and secondary spray cooling system have been almost completed.[1,2] The continuous casting machine itself has been made highly sophisticated, with its operations getting more complicated. In particular, the operators' work on the casting floor requires various manipulations and operations to be done in a very limited time. These operations are mainly incidental work performed in the high temperature environment, involve the handling of heavy materials, and call for a considerable level of skill. These jobs require workers to be close to high temperature materials, or to be in a molten steel splashing environment, with performances highly dependent on the skill of individual workers, thus accuracy of work not always guaranteed. The reliability and safety of operations are improved by automatization and mechanization.

In the continuous casting shop of Kawasaki Steel, a number of manual operations have been automated covering processes from ladle setting to finishing, as part of an equipment rationalization program. To be more specific, these include the coupling and decoupling of wiring and piping for ladles, replacing of tundish immersion nozzles, charging of coolants at sequential continuous casting of different chemical compositions, and sampling of hot slabs. This report explains the details of

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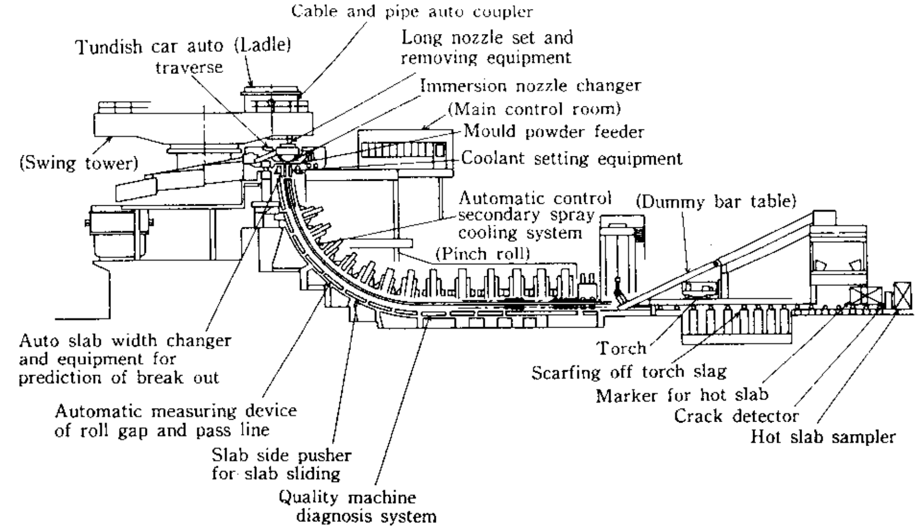


Fig. 1 Schematic diagram of automated equipment in continuous casting process

the automated equipment and its operations.

2 Continuous Casting Process and Automatization

The control of chemical composition and temperature of steel as well as its solidification in the continuous casting process is automated by much effort to a fairly high level-up to this point.[1,2] However, the incidental work such as the preparation or scheduling for casting is still left to skilled workers even now, requiring improvement in manpower saving and working environment.

An outline of continuous casting machine and automatization equipment is shown in **Fig. 1**. Automatization or reduction of labor in the continuous casting process calls for a number of important points which can be itemized as follows:

(1) Elimination of unsafe operations and operations involving the handling of heavy materials,
(2) Reduction of the overlapping of busy work,
(3) Shortening of operating hours,
(4) Prevention of intervention between the function area of equipment and that of operators,
(5) Good reliability and maintenability of equipment.

Furthermore, since most of the existing equipment are not engineered to be suitable for automatization, the area where automatic equipment is located is not only narrow, but also restrictive. Therefore, it is necessary that the automatic equipment be designed for good operation, compact structure, and easy installation.

3 Cable and Pipe Autocoupler for Ladle

Recently the molten steel flow from the ladle is controlled by the sliding nozzle instead of the conventional stopper type manual operation. In the sliding nozzle type, a remote control operation is possible at the pulpit, but it is necessary to connect the power cable and gas pipe between ladle and casting floor. Hitherto, the connection was done manually. In October 1985, the autocoupler using remote control was developed and went into operation.

3.1 Composition and Distinctive Features

This equipment functions by remote control so as to couple or decouple the cable and pipe necessary to control the opening and closing of the sliding nozzle of the ladle. As shown in **Fig. 2**, this equipment consists of the coupler on the swing tower and the joint mounted on the ladle side. **Table 1** shows the equipment specifications.

As a first of the features of this device, this unit uses a low contact-resistance pin for the weak electric current circuit (resolver, for EMLI detector) so as to effectuate

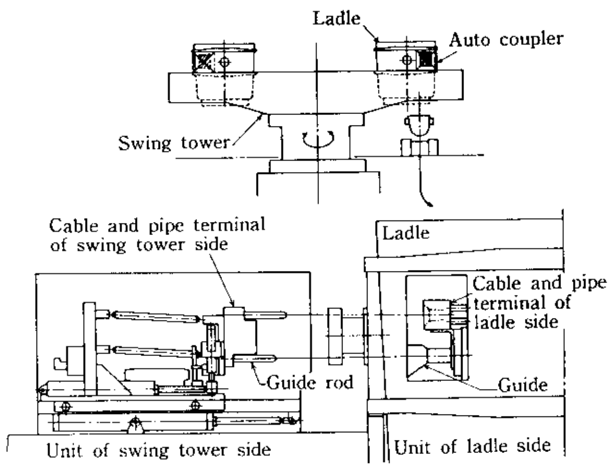


Fig. 2 Cable and pipe auto coupler for ladle

Table 1 Specifications of cable and pipe auto coupler for ladle

Item	Specification
Driving method	Pneumatic drive (Elec. control)
Centering method	Ram system
Adjustable range	
Vertical	50 mm
Horizontal	
front and rear	±150 mm
right and left	±200 mm
Incline angle	2°
Twist angle	±3°
Auto coupler	
Pipe*1	25A×4
Cable*2	3 units

*1 Pipe for cooling gas of sliding nozzle unit and injection gas for nozzle.
*2 Cable for sliding nozzle resorva, EMLI detector for nozzle open and shut, and power for sliding nozzle.

an automatic coupling. After the centering by use of guides, the accurate centering is achieved by coupling the high power current circuit (for power source and limit switches). At last main cable and pipe are coupled. And, the multi-electrical transmission method using FM electric wave of the wire system is adopted for sending instructions from the pulpit to the swing tower. By this method, 17 kinds of message and information can be given and received through the 2 slip rings.

3.2 Operation

Just after the start up of the operation, troubles of incomplete coupling occurred because of the deformation by heat of the joint on the ladle, and the adhesion of the metal to the coupler during the receiving of molten steel into the ladle or the refinement of steel, as well as the deviation of ladle setting on the swing tower. To solve these problems, a protector was installed on the ladle side, and the coupling unit was remodelled so as to accommodate the torsion or slant of a ladle. Furthermore, a test device for checking the soundness of ladle condition after the scheduling was made, and the ladle is checked before using it on the swing tower. This equipment is employed in a good condition now, and the coupling and decoupling operation of cable and pipe have become more secure than conventional method, with no operators required to approach the ladle.

4 Tundish Immersion Nozzle Changing Equipment[3)]

The immersion nozzle is used to seal molten steel stream between the tundish and the mould from the air. In most of the case, it is necessary to set or change the nozzle as red-hot and it has to be done rapidly. When casting starts up, operator attaches a preheated new nozzle before setting the tundish. During the casting, if this nozzle is worn out or the wear of nozzle is foreseen, the operators stop the casting, lift up the tundish, and replace the immersion nozzle. This method assures the good quality of slab and the prevention of the machine stop in continuous casting operation while making possible sequential continuous casting.

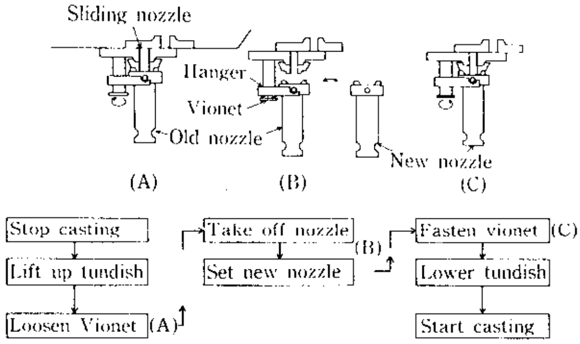


Fig. 3 Flow of tundish immersion nozzle changing

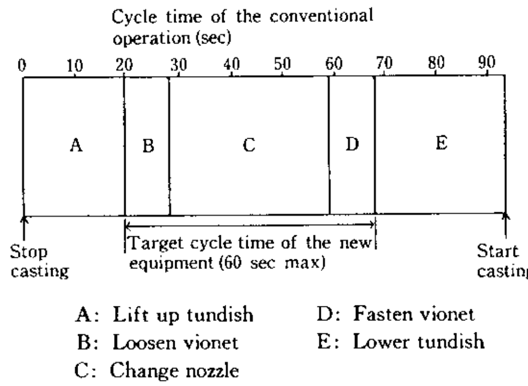


Fig. 4 Target cycle time for the nozzle changing

Figure 3 shows the nozzle replacing procedure. Formerly, this work was performed manually, namely, an operator carried a preheated immersion nozzle to the designated replacement place under the sliding gate of the tundish, replaced as quickly as possible so as to continue casting. This operation is dangerous because of the possibility of burn by accidental contacting with the red-hot immersion nozzle during transport, or the molten steel leakage from the sliding gate. As a matter of fact, it can be said that the operation stability and safety were guaranteed only by the skill of operators. If the accident occurs once, it is impossible to continue this work and a large reduction of productivity is not avoidable.

At an initial stage of the automatization of this work, actual operations were analyzed and the automatization was designed so that a target time may be 90 seconds from the time when the tundish closes the sliding gate, moves up, and comes down to open the gate (**Fig. 4**). Number 1 equipment started operation in 1984, and now 8 units of the equipment are in operation.

4.1 Structure and Specifications of Equipment

The necessary functions of this equipment are following three points:

(1) Fitting and removing the nozzle at preheating place
(2) On-line nozzle replacing
(3) Preheating the nozzle and automatic handling

Of these functions, particularly No. (2) needs a higher degree of accuracy and rapidity, and this also requires a complex movement. To satisfy these functions, this equipment consists of a replaceable unit of the nozzle, a handling unit of the nozzle, and a preheater. Construction and movement of the equipment are shown in **Fig. 5**.

The location of on automatic equipment is bound to be confined in a limited space available among the existing equipment. This equipment is installed on the transfer car which is connected to the existing tundish car, because this type is considered to be better for operation and safety. The layout for the two-strand type of continuous casting machine is shown in **Fig. 6** as a transfer car type connected to the tundish car. The two-hand type is introduced to shorten operating time.

For safety measure, all units of this equipment are grouped at the non-operating side to avoid the interfere with the working area of swing arm and operators. Furthermore, posters and indications based on the "Rules on labor safety and health involving industrial robots" and a fail-safe function were demonstrated to the fullest extent. The specifications of this device is shown in **Table 2**.

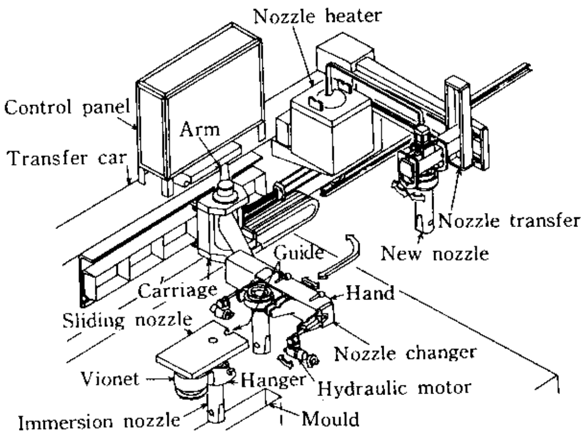
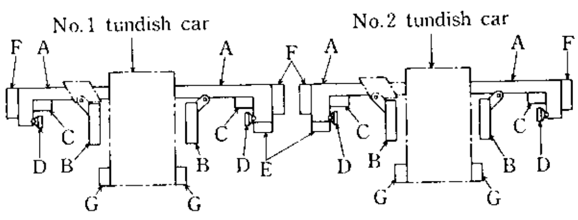


Fig. 5 Tundish immersion nozzle changing equipment



A: Transfer car B: Nozzle changer
C: Nozzle heater D: Nozzle handling
E: Coolant pusher F: Control panel
G: Operating panel

Fig. 6 Layout around the tundish car

Table 2 Specifications of tundish immersion nozzle changing equipment

Item	Specification
No. of equipment	1/mould
Driving method	Hydraulic and Pneumatic drive
Cycle time	60 sec*1
Adjustable range	
Width side of mould	±30 mm
Thickness side of mould	±70 mm
Vertical direction	−5 mm～+25 mm
Twist angle	±0.5°
Max. torque for vionet	60 kg·m
Nozzle heater	LPG burner with air blower, 60 min for heating from 20°C to 1 100°C
Nozzle	
Max. weight	40 kg
Length	730 mm

*1 Excluding the tundish moving time

4.2 Device for Exchanging the Nozzle

This device, which automatically replaces immersion nozzle set at the sliding gate below the tundish, consists of carriage unit, hand unit, and auxiliaries of guide attached to the sliding gate. This device transfers immersion nozzle to the sliding gate suspended from hand unit, and removes an existing nozzle and installs a new one.

(1) Carriage

The carriage has guide rollers and moves in a reciprocating motion by a hydraulic cylinder in the horizontal direction along the rail installed on the attached car. This device is equipped with a rotable arm. It is so designed that as the guide roller at the tip of the lever installed at the central boss of the arm's rotation glides into the guide slot on the upper surface of the attached car, the arm rotates in a fixed locus along with the movement of the carriage.

(2) Hand Device

The hand which suspends the immersion nozzle is installed on the arm, and can move in the horizontal direction by pneumatic cylinder. On its both sides, there are two hydraulic motors to fasten the vionet of the sliding nozzle. These two hydraulic motors are so designed that they oscillate jointly through a link mechanism by the pneumatic cylinder. A propeller which can rotate the vionet is installed at the shaft end of the hydraulic motor and can adjust the center line automatically. Two convex-type guides installed on the hand slide into a concave guide installed on the sliding gate so as to adjust the center line of the hydraulic motors to that of the vionet.

(3) Sliding Gate

This device consists of three parts; (1) a hanger supporting case with a spiral shaped groove as an improvement over the existing parts, (2) a rotating sleeve with a convex shape projection that slides into the spiral groove, and (3) a stopper that stops the sleeve rotation at a designated point. The rotating sleeve has two shafts at the lower parts so that the propeller mentioned above can slide into the shaft. Operator can rotate this sleeve manually by turning the lever mounted on the side of the rotating sleeve.

4.3 Device for Nozzle Handling

This is used to receive and accept an immersion nozzle between the exchanging device and preheater box, and consists of the rotative bracket, carriage, clamping, and chimney. The rotative bracket and the chimney are supported on the attached car, and can rotate together by the linking mechanism. On the rotative bracket, a carriage having hooks designed to open and close is mounted to move up and down in a virtical direction. This device makes an immersion nozzle suspended from the hooks move vertically and rotate so as to receive and deliver the nozzle at a designated point. These functioning are carried out by pneumatic cylinders.

4.4 Nozzle Heater

This device heats an immersion nozzle and consists of gas blower, solenoid valve, gas burner having an electric ignitor, and heating box. These are installed at the side of the attached car. The ignition of the pilot burner to the automatic ignitor is carried out by the spark of a 7 000-V ignition transformer. The gas burner uses LPG gas, with its capacity 10^5 kcal/h, and the surface temperature of an immersion nozzle reaching a maximum of 1 200°C.

4.5 Operation

The measurement of necessary operating time after start-up of this equipment is shown in **Fig. 7.** This shows that this method can exchange an immersion nozzle in nearly the same time as the existing manual method shown in Fig. 4. Operation can be made by only one operator for one mould instead of conventional two operators, with reduction of labor at the peak time achieved.

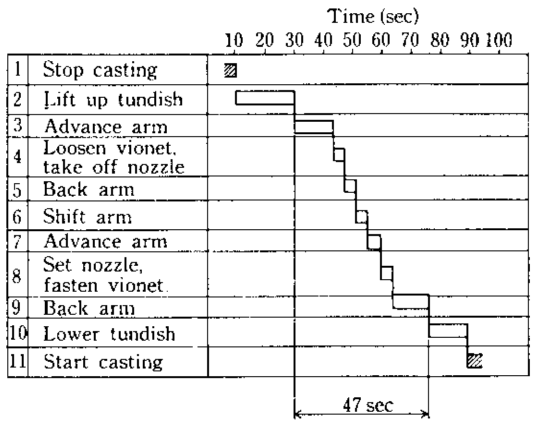


Fig. 7 Cycle time for the tundish immersion nozzle changing

This equipment is in a good operation now without any trouble. In safety measures, setting up of a safety fence around the working area of this equipment was all that was necessary.

Other than the increase of safety and the decrease of operators, the stability of nozzle handling and the constant clamp force of nozzle brought about a decrease in the operating troubles and an increase in productivity.

5 Equipment for Charging the Coolant[3)]

The coolant is charged in the order shown in **Fig. 8** during tundish exchanging at a sequential continuous casting of different chemical compositions in order to minimize the mixing of two steels. This coolant has to be charged into the mould during a short period of time after the casting when old tundish rises up and leaves the casting position and new tundish approaches there; namely, coolants must be charged before the top solidified shell in the mould begins to shrink, and must be pushed into a specified position. In conventional method as shown in Fig. 8, two or three operators on the mould placed the coolant into the mould. With such danger involved in this operation as a fall into the mould or a sprash out of molten steel by bumping, the safety of operator during the charging of coolant was left entirely to the operator's caution. If the operating trouble once

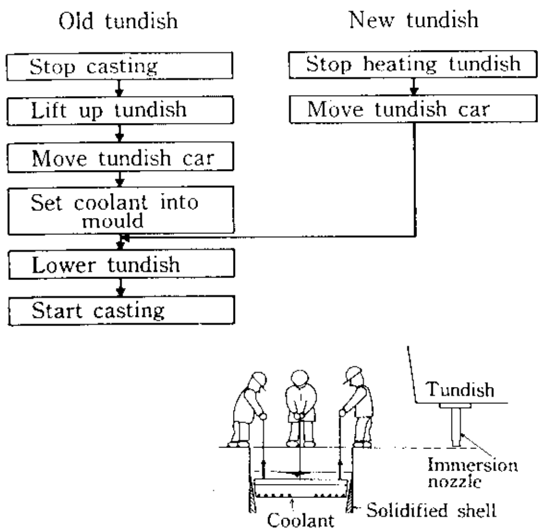


Fig. 8 Flow of the coolant setting

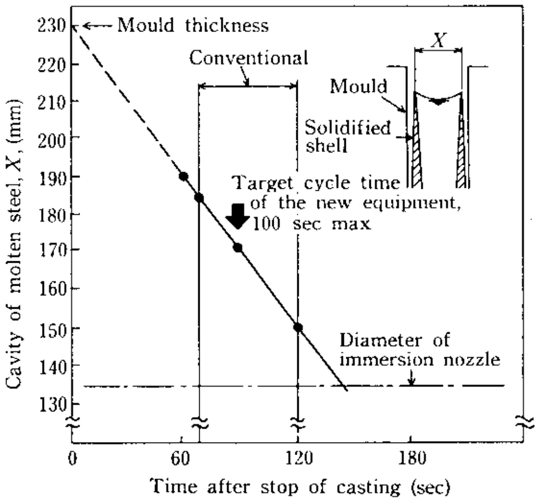


Fig. 9 Change in cavity of molten steel after stop of casting

happens, the operators must stop the work at the sacrifice of a large productivity drop.

In the case where the operation had to depend on manual type, the sequential continuous casting of different chemical compositions was impossible, because the coolant for the large cross-section of slab is too heavy for operators to handle (max. weight 100 kg). In mechanizing these operations, the plan for this operation's target time was set at 100 seconds maximum, since the time from the rise and traversing of the old tundish to the approach of new tundish was 70 to 90 seconds. This value, as showing in **Fig. 9**, must be less than 100 seconds at maximum, because the thickness of molten steel of the top parts in the mould becomes small in proportion to the lapse of time after the supply stop of molten steel from the tundish, and also because the width of the molten steel in the mould must be larger than the size of the coolant or immersion nozzle for the easy inserting into the mould.

5.1 Structure and Specifications of Equipment

The necessary functions of this equipment are the following two points:

(1) Holding, receiving, and delivery of the coolant

(2) Pushing of the coolant

This is not so intricate operation, but this equipment must have good centering property with which it adjust itself to the shrink of the solidified shell in the mould during the tundish changing. This equipment consists of a device for charging coolants and a shift car, as shown in **Fig. 10**.

Because the charging operation is done during the tundish changing and the continuous casting machine consists of two strand as shown in Fig. 6, this equipment is installed on each transfer car respectively set up within the two tundish cars, and the center of this equipment was set at the mould center. To reduce the operation time, two equipment can operate at the same time. Specifications are shown in **Table 3**.

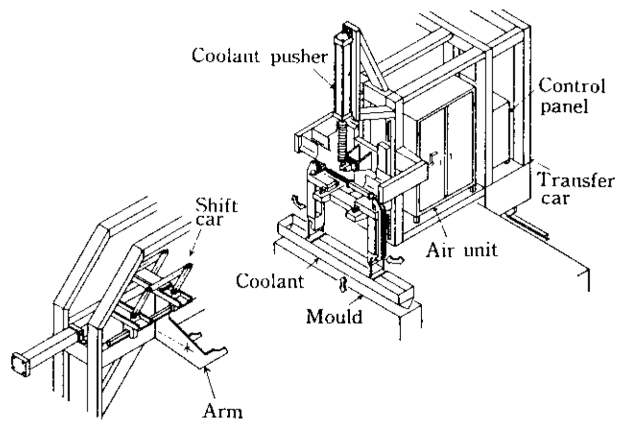


Fig. 10 Coolant setting equipment

Table 3 Specifications of coolant setting equipment

Item	Specification
No. of equipment	1/tundish car
Driving method	Pneumatic drive
Cycle time	90 sec*1
Adjustable range	
Thickness side of mould	±50 mm
Stroke of vertical direction	0~1 000 mm
Pusher	
Pushing force	50 kgf~300 kgf
Holding time	0~180 sec

*1 Including the traverse time of tundish car

5.2 Coolant Pusher Proper

This equipment consists of an upper carriage and a lower carriage which move up and down along the two guide rails vertically installed to the attached car. The lower carriage is so designed that it can move up and down in the upper carriage by pneumatic cylinder. On the lower carriage, the clamping stand having two hooks that opens and closes by penumatic cylinder is mounted in a manner movable in the linear way and can move to the center line of the mould while descending. Further, a position-locating car and a shift car are mounted on the shift frame installed horizontally to the attached car. The position-locating car is the device for presetting the clamping stand to the mould center and is adjustable by rotating the manual handle.

5.3 Shift Car

The shift car has arms that suspend the coolant and can move horizontally by the pneumatic cylinder on the shift frame fitted horizontally to the attached car. This device can deliver and receive the coolant suspended on the clamp device of the pusher by the link mechanism. Further, the transportation of the coolant at the casting floor is performed by using a handcart having a stepping-type lifting device. The coolant is transferred to a specified place and is suspended on the arm by the link mechanism mentioned above.

5.4 Operation

This equipment began operation in October 1984. The operation has been stable with hardly any trouble, with many operational advantages.

(1) The working time was 93 seconds, as shown in **Fig. 11**, as compared with the target time 100 seconds. This value scattered from 71 seconds to 130 seconds in the case of manual operation, but became about regular by automatization. Troubles such as breakout or molten steel leak, which used to occur when this operating time exceeded 100 seconds, are entirely stopped by this equipment. This is considered to be attributable also to the charging of the coolant in perfect horizontal and the fixation of the position made possible by this equipment other than the constant working time.

(2) Two or three operators required per one mould in conventional method were reduced to only one operator in charging the coolant by new method. Further, the remote control operation made available assures safety.

(3) This equipment permits charging of the coolant for slab of the largest cross-sectional size, thereby making it possible to cast a sequential continuous casting of different chemical compositions for practically any shape of slab for a higher productivity.

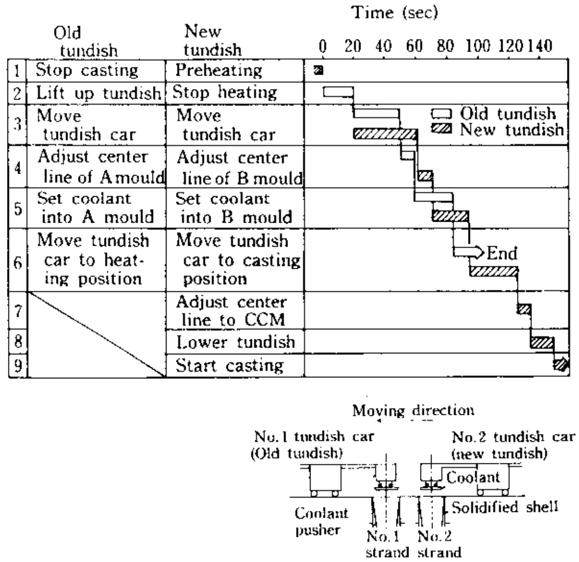


Fig. 11 Cycle time of coolant setting equipment

Furthermore, it has made it possible to charge the coolant for top treatment of largest cross-sectional slab size, thereby preventing the inclusions.

6 Quick Sampler from Hot Slab

It is very important to sample the slab at the lowest bottom, the highest top and the interface of sequential continuous casting of different chemical compositions, and to reflect the analysis of chemical compositions quickly in manufacturing process. Conventional sampling method was the drill sampling or the gas cutting by manual work performed off-line of slab flow. This method needs many operators and long time, and heat loss was great because of the necessary cooling of the slab. Since it is very important to get the analysis quickly to solve this problem, the analysis method was changed from a wet type to the instrumental analysis using a solid sample. As sampling equipment, the mechanical cutting sampler shown in **Fig. 12** was developed in October 1986, and was installed in the slab treatment yard.

6.1 Composition and Distinctive Feature

An outline of this equipment is shown in Fig. 12. Samples of a slab are taken on the sampling table roller. The slab sampling positions are the upper surface of bottom side and the edge face of top side. A slab can be taken into and out of the sampling position by using the table roller or by using cross feeding from the right side of the figure. During sampling, a slab is fixed at the center of the roller by the clamping device.

A sample obtained by cutting is sent to the analysis

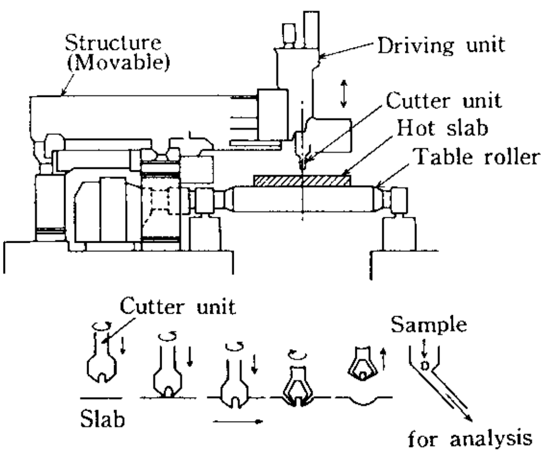


Fig. 12 Hot slab sampler

center by chute. The hot slab sampler is operated by remote control except that an operator casts a sample into the chute by hand. This device assures a quick sampling of slab of temperatures from the room temperature to 800°C.

6.2 Operation

The actual results of sampling time taken at the upper surface of the bottom slab is shown in **Table 4**. The time is from the stop of slab movement at fixed point, centering the cutter unit, and taking one sample to the restart of the slab. Since the cutting mode is changed depend on the temperature and material quality, the sampling time scatters, but samples can be taken in 3.5~5 minutes.

The concave on the surface of slab after sampling is the semi-spherical shape, and this slab can be rolled as it is without any problem.

This equipment is in a good operating condition, after an improvement required only in heat protection measures. Furthermore, the time from sampling to finding the analysis is shortened from about 1 day in conventional method to within 30 minutes, thanks to the changing of the analysis method, with noticeable effect on the reduction of the lead time and an increase in slab hot charging.

7 Conclusions

In the operation of the continuous casting process, the following equipment was developed and put in operation for the automatization of manual work by operators in an environment exposed to high temperatures.

(1) By installing the cable and pipe autocoupler for a ladle on the swing tower, the work is made to be performed by remote control just before and after casting. An operator is no longer required to approach the ladle.

(2) An immersion nozzle changer for the tundish was installed on the car. Also, the nozzle heater was installed at the same time so that the hot nozzle could be changed by remote control. An operator is no longer required to go under the tundish, with additional merit of safety.

(3) The charging equipment of the coolant for the sequential continuous casting of different chemical compositions was installed on the tundish car. Operators are no longer required to stand on the mould cover in charging heavy coolants. The charging of the coolant into the mould was assured.

(4) The automatic rapid sampling machine for hot slab was installed at the slab treatment yard. For sampling, the machine cutting method was used, making it possible to sample a slab upto 800°C, thus leading to an expansion of hot slab charging.

Table 4 Sampling time*[1] of hot slab sampler (sec)

Slab material \ Temperature of slab (°C)	20°C	300°C	500°C	700°C
Low carbon steel	215	243	282	251
Middle carbon steel	215	243	282	251
High carbon steel	220	243	311	271

*1 Time periods between the stop of slab movement to take one sample and the restart of it.

The mechanization and automatization of the equipment described above could not have been possible without a joint development effort with cooperation from Nippon Air Brake Co., Ltd. and Kawasaki Heavy Industries, Ltd.; the former for the cable and pipe autocoupler for the ladle, and the hot slab quick sampler, and the latter for the immersion nozzle changer for the tundish and the charging equipment of the coolant.

At the end of this report, the authors would like to express their sincere thanks to all persons concerned of these companies for their kind and efficient cooperation.

References

1) Y. Iida, M. Maeda, K. Emoto, S. Yamasaki, K. Orito, K. Hirata, M. Ueda, and A. Takahashi: *Kawasaki Steel Giho*, **12**(1980) 3, 110
2) K. Tsuboi, K. Sano, Y. Horiuchi, S. Komori, I. Tsuboi, and T. Wada: *Nippon Kokan Technical Report*, No. 93 (1982), 93
3) S. Shiraishi, S. Hiwasa, Y. Iwanaga, H. Kaneko, E. Inoue, and A. Murata: *Tetsu-to-Hagané*, 71(1985) 4, S154