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3,614,978

3 Sheets-Sheet 1

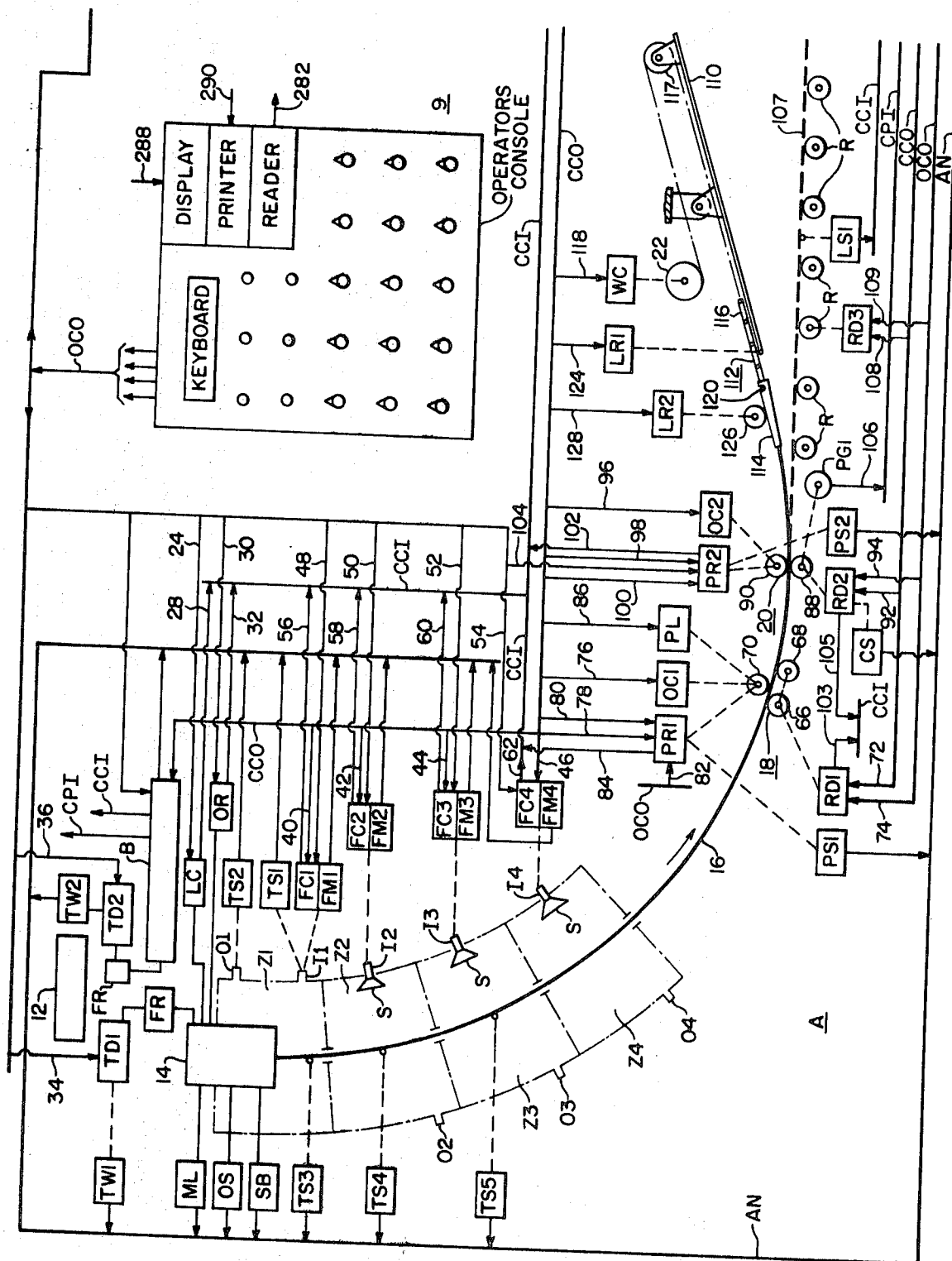


FIG. 1A:

WITNESSES

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Oct. 26, 1971

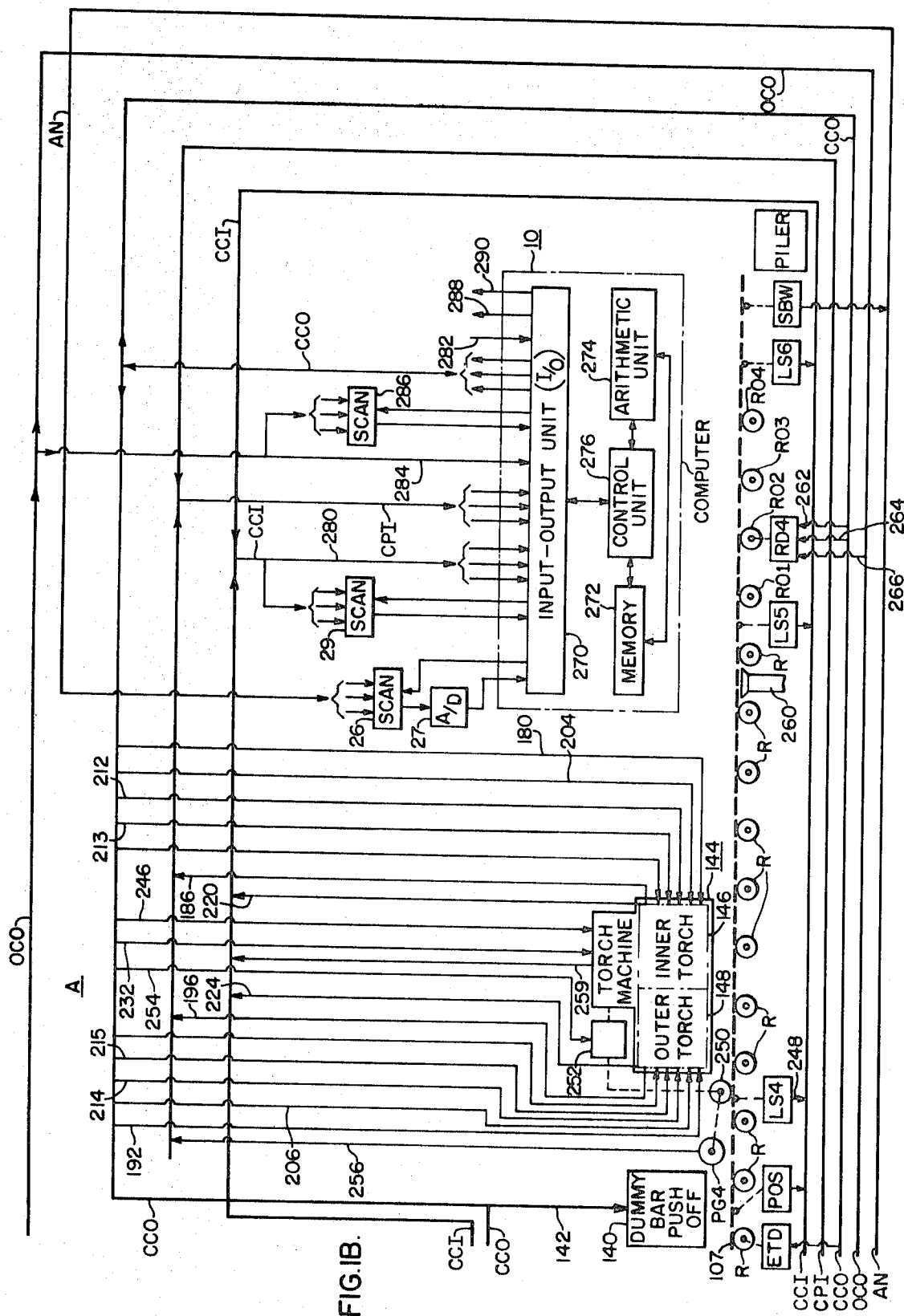
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COMPUTERIZED CONTINUOUS CASTING SYSTEM CONTROL
RESPONSIVE TO STRAND POSITION

Filed July 1, 1968

3 Sheets-Sheet 2



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3,614,978

**COMPUTERIZED CONTINUOUS CASTING SYSTEM
CONTROL RESPONSIVE TO STRAND POSITION**Michael A. Kosco, East McKeesport, Pa., assignor to
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16 Claims

ABSTRACT OF THE DISCLOSURE

Computer controlled continuous casting of materials from the molten to the solid state. The computer keeps tracks of the position of the moving cast strand of each of a plurality of casting lines from the time it emerges from the mold and, in response to position of the strand, controls various elements at the proper time along the casting line, such as coolant flow, pinch rolls, straightening roller, dummy bar head separation, table or conveyor rolls, and slab cutting machine. The computer keeps track of the slab cutting machine and the position of its cutting elements, and controls the cutting operation in synchronism with movement of the strand. Also in response to position of the moving strand, the computer at appropriate times begins to monitor and compare against stored references such conditions as coolant and strand temperatures, coolant flow rates, pinch roll drive current, and pinch roll pressure. The computer also performs a pre-pour diagnostic check-up on various elements of the casting line to determine if a malfunction exists. Additionally as the casting progresses, the computer gathers and outputs information as a function of position and time with respect to each strand. The computer controls a plurality of casting lines in "parallel" by suitable multiplexing.

BACKGROUND OF THE INVENTION

This invention relates to the operation of systems wherein metal is cast in a continuous billet by pouring molten metal into a fluid-cooled mold and continuously withdrawing the metal as it solidifies from an opening in the mold by means of withdrawal devices. As the billet (commonly referred to as "strand") emerges from the mold, it is characterized by a solid exterior enclosing a molten interior, and as the strand progresses it passes through an auxiliary cooling area to further solidify the strand. Further along the casting "line" the billet is cut in suitable slab lengths by a cutting mechanism for example a torch cutting machine. Initially the start end of the strand is pulled out of the mold by a dummy bar attached to the start end of the strand, and before the slab cutting mechanism is reached, the strand is generally separated from the dummy bar. The withdrawal mechanism usually includes pinch rolls that drive the dummy bar and later drive the strand after it reaches the pinch rolls. In some systems human operators control various elements of the system and also check gauges and other sensors detecting various conditions such as fluid coolant temperatures and flow rates, strand skin temperatures, pinch roll pressure, etc. There have been proposals heretofore of various degrees and methods of automating different parts of such a system. Prior art attempts at automation generally were directed to control in response to properties of the cast strand and of the elements of the system such as strand and coolant temperature, solidity of the strand, etc. It has even been proposed to computer-control the continuous casting system in accordance with a highly complex formulation involving properties of the strand and conditions of system elements. I am unaware of any successful application of such complex computerized control.

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SUMMARY OF THE INVENTION

The invention is directed to improved computer controlled methods of and apparatus for controlling a continuous casting system. One of the objects is to provide such control in a simple but effective and accurate manner without resorting to complex formulation.

Another object of the invention is to enhance the capabilities of the system whereby a high throughput consistent with acceptable quality is achieved.

In accordance with one embodiment of the invention pulses generated as the cast strand advances are accumulated in a computer whereby the computer knows the position of the advancing strand and in response to arrival of the strand at successive points along the line applies control functions to devices along the line in the order of succession of the devices. Each device affects in some manner the cast product. The devices may for example be water spray control, pinch roll control, slab cutter control, and others. In response to relative positions of the strand, the slab cutter, and the cutter elements of the slab cutter, the traverse of the cutting members is controlled by the computer to be in timed relation with the moving strand so that the cut is finished at a predetermined point along the line.

Other and further objects and advantages of the present invention will become increasingly apparent from the following detailed specification taken in connection with the accompanying drawings which illustrate a preferred embodiment of the invention in connection with apparatus for continuously casting steel.

IN THE DRAWINGS

FIGS. 1a and 1b taken together side-by-side with FIG. 1a to the left form a composite block diagram of a continuous casting system incorporating computer control in accordance with the invention;

FIG. 2 is a block diagram illustrating details of the torch machine shown in FIG. 1b.

**DESCRIPTION OF THE PREFERRED
EMBODIMENT**

In FIGS. 1a and 1b, two similar continuous casting lines A and B are shown with elements thereof monitored and controlled by control apparatus including an operator's control console 9 and a digital computer 10. Since the casting lines A and B are similar, only one, casting line is shown in detail, casting line B being shown only as a single box. It may be noted that casting line A extends across the FIGS. 1a and 1b, taken together.

Molten material, for example steel, is supplied by a ladle 12 to tundishes TD1 and TD2 that in turn supply the molten steel at controlled rates to the molds of the respective casting lines A and B. The mold at the head of casting line A is indicated at 14 and typically is provided with an open top to receive the molten steel from tundish TD1, and a bottom opening from which the cast product for example a strand 16 is withdrawn. Although the strand 16 is shown diagrammatically as a thin line, it in fact may be of considerable cross-section, for example forty inches wide and seven inches thick. For the example shown, the withdrawal drive is provided by pinch roll sets 18 and 20 and to some extent by a dummy bar winch 22, all in a manner as later described.

Conventionally, mold 14 may be lined with copper and provided with means for lubricating the mold and for oscillating the mold. Lubrication of the mold liner is provided by a suitable lubrication control LC controlled from the operator's console 9 via a control line 24, and the lubrication rate is sensed by a suitable sensor ML that transmits signals representing lube rate to the computer through a multi-conductor cable AN, a scanner 26 and an A/D (analog-to-digital) converter 27. Cable AN is so

labeled because its conductors carry analog signals. Control line 24 passes through a multi-conductor cable that is labeled OCO because its conductors carry the various outputs from the operator's control console 9. Diagnostic status (for example operative or inoperative) of the control LC is communicated to the computer as a CCI (contact closure input) through a signal line 28 and a multiplexer 29. Signal line 28 passes through a multi-conductor cable that is labeled CCI because its conductors carry signals from contact closure inputs (CCI's).

Oscillation of the mold is controlled by a suitable oscillator drive regulator OR controlled from the operator's console through a line 30, and the oscillations are sensed by a suitable oscillator sensor OS whose output is transmitted to the computer through cable AN, scanner 26 and the converter 27. Diagnostic status of the control OR is transmitted as a CCI to the computer through a line 32 and scanner 29.

The flow of molten metal from tundish TD1 to the mold 14 is regulated by a flow regulator FR in accordance with the withdrawal rate from the mold as evidenced by the level of the metal in the mold. Suitable weight sensors TW1 and TW2 supply to the computer, output signals representing the weights of tundishes TD1 and TD2 respectively. A suitable slag binder, sensor SB supplies to the computer (through scanner 26), signals indicating the slag binder speed in the mold 14. ON and OFF pour control for the tundishes is provided by signals from the operator's console 9 via lines 34 and 36.

Adjacent to and surrounding at least a portion of the mold is a cooling zone Z1 followed in consecutive order, downstream along the casting line, by cooling zones Z2, Z3 and Z4. These zones are defined by suitable enclosures so that coolant, for example water, may be applied to the mold in zone Z1 in liquid form, and to the cast strand 16 as it passes through zones Z2, Z3 and Z4 in a spray form.

Cooling zones Z1, Z2, Z3 and Z4 are provided with coolant inlets I1, I2, I3 and I4, respectively, each connected through its own flow control FC to a source of coolant not shown. Coolant inlet I1 also has coupled thereto a temperature sensor TS1 for supplying to the computer signals representing the temperature of the coolant at the inlet. Each of the inlets has also coupled thereto a flow meter FM for generating and transmitting to the computer (through scanner 26), signals indicating the rate of coolant flow to the respective inlets. More specifically, inlet I1 has coupled to it flow control FC1, flow meter FM1 and temperature sensor TS1. Inlet I2 has coupled thereto flow control FC2 and flow meter FM2. For inlet I3 the flow control and flow meter are at FC3 and FM3 respectively, and for inlet I4 these instruments are at FC4 and FM4 respectively. Each of inlets I2, I3 and I4 is also connected to a spray head S extending into its associated zone for spraying coolant onto the strand 16 as it passes through that zone.

Indicated at O1, O2, O3 and O4 are coolant outlets for zones Z1, Z2, Z3 and Z4 respectively. These outlets may be connected as a return to the coolant source or to a waste disposal system. Usually zone Z1 associated with the mold has a separate closed cooling system whereby inlet I1 and outlet O1 are coupled to a separate source of coolant, while the inlets of the other zones are connected to another source of coolant. Coupled to the coolant outlet O1 is a temperature sensor TS2 for transmitting to the computer a signal representing the temperature of the outgoing coolant from zone Z1.

Each of the flow controls FC1, FC2, FC3 and FC4 is operable to ON or OFF as desired in response to commands from the computer via lines 40, 42, 44 and 46, respectively, passing through a multi-conductor cable that is labeled CCO because its conductors carry contact closure outputs (CCO's). These flow controls are also adjustable via lines 48, 50, 52 and 54 from the operator's console 9 to change the rate of coolant flow. Diagnostic status

information of these flow controls is supplied to the computer 10 along lines 56, 58, 60 and 62 and scanner 29.

For measuring the skin temperature of the strand 16 as it passes through zones Z1, Z2 and Z3, suitable temperature sensors TS3, TS4 and TS5, respectively, are placed in the zones along the course of the strand to generate and transmit to the computer signals representing these temperatures.

Referring again to the mold 14, it is shown as a curved mold whereby the cast product is curved to the right as it is drawn downward. It will be noted that the defining means for the respective cooling zones also form an arcuate course along which the advancing strand 16 is guided.

Downstream of zone Z4 is the set of pinch rolls 18 which includes driving rolls 66 and 68 and a downwardly forced pressure roll 70, the strand 16 being pinched between the pressure roll 70 and the bottom drive rolls 66 and 68. Although shown as driven by a single roll drive unit RD1, rolls 68 and 66 may be driven separately if desired. Drive unit RD1 is controllable to ON and OFF by computer command along an input line 72 to be run at a preset speed selected by the operator through signal line 74.

Pinch roll set 18 is opened or closed by a controller OC1 in response to computer commands via line 76. Roll pressure for the set 18 is controlled by a pressure control unit PR1, which on command from the computer along line 78 operates to compress or decompress the roll set, and selectively calls for high or low pressure on the rolls on command from the computer via line 80. Pressure on the rolls 18 may be adjusted from the operator's console 24 through a line 82. Diagnostic status of the roll pressure control system is transmitted to the computer via line 84 (passing through cable CCI) and scanner 29. The roll set 18 may be locked in closed position on command of the computer through a line 86 applied to a pinch lock control PL. Pressure of the roll set 18 is monitored by the computer through a pressure sensor PS1 outputted through scanner 26.

Pinch roll set 20 includes a bottom drive roll 88 and an upper pressure roll 90. Roll 88 is driven by a roll drive unit DR2 which is controlled to ON and OFF by computer command along signal line 92, and which operates roll 88 at a preset speed selected from the operator's console 9 through line 94. The drive current is monitored by the computer through a current sensor CS outputted through scanner 26. Pinch roll set 20 is provided with a controller OC2 for opening and closing the pinch rolls on command from the computer through a line 96. Roll set 20 is also provided with a pressure control unit PR2. High or low pressure is selected on computer command via line 98 and compress and decompress status of the rolls is selected by computer command through line 100. Diagnostic status of the pressure control unit PR2 is transmitted to the computer via line 102 and scanner 29. The roll pressure of pinch roll set 20 may be adjusted from the operator's console 24 through a line 104.

Pressure of the roll set 20 is monitored by the computer through a pressure sensor PS2. A pulse generator PG1 coupled to the drive roll 88 generates a pulse for each successive equal predetermined increment of angular travel of the drive roll, and thereby for each successive equal predetermined increment of travel of the cast strand being worked on with the aid of the roll set 20. These pulses are transmitted along a line 106 to the computer as CPI's (computer process interrupts) passing through a cable that is labeled CPI because it carries process interrupts. The frequency of these pulses is used by the computer to calculate the casting speed of the strand, and the accumulation of the pulses is used to calculate the location of the front end of the strand and the total length of the stand.

Diagnostic statuses of roll drive units RD1 and RD2 are

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transmitted to the computer through lines 103 and 105 and scanner 29.

Downstream of the pinch roll set 20 are a plurality of motor driven conveyor rolls R spaced along the normal course of travel of the cast strand and cut slabs, which course is indicated by the dashed line 107 running along the tops of the conveyor rolls R. Although each of the rolls R is individually motorized, the drive unit for only one of the rolls is shown at RD3. Drive unit RD3 is operated ON or OFF by computer command along a line 108 at a preselected speed set by the operator's console 9 via line 109. It will be understood that each of rolls R has a similar controlled drive unit coupled thereto.

Downstream of the pinch rolls 20 is a rocker arm 110 for guiding a dummy bar 112, the latter comprising a dummy bar head 114 coupled to a dummy bar chain 116. The dummy bar chain passes around a pulley 117, and its other end or a cable attached thereto is wound around the drum of the winch 22 which is controlled for wind-up or pay-out under command of the computer through a line 118 applied to a winch controller WC. A drive unit LR1 coupled to the rocker arm 110 operates to selectively lower or raise the rocker arm in response to computer command through a line 124. The dummy bar head is detachably coupled to the dummy bar chain by an arrangement wherein a pin 120 fixed to the end of the dummy bar chain is disposed in the upwardly directed open jaws of a hook-shaped end of the dummy bar head. The fit is tight enough so that they do not normally fall apart, but will be forced apart in response to a downward push on the dummy bar head by a straightener roll 126.

Disposed between the pinch roll set 20 and rocker arm 110 is the roll 126 which has the dual function of uncoupling the dummy bar head from the dummy bar chain and straightening the cast strand 16 along the horizontal path 107 as it emerges from the pinch roll set 20. Roll 126 is selectively lowered or raised by a suitable drive unit LR2 under computer command through a line 128.

A limit switch LS1 disposed along the casting line transmits a signal to the computer when the cast strand reaches the position of the limit switch, whereby the computer recalibrates the position of the strand. Up to that point the calculated position might have varied $\pm$ one inch due to slippage, stretching, etc. thus, the desirability for recalibration.

Downstream of the rocker 110 is a dummy bar head push-off mechanism 140 (FIG. 1b), operable under control of the computer through a line 142. A push-off sensor POS, for example, a limit switch is actuated if the dummy bar head is in fact successfully pushed off, thereby to transmit a signal to the computer through scanner 29.

To the right of the dummy bar push-off mechanism 140 is a slab cutter in the form of a torch cutting machine 144 which is provided with an inside torch 146 and an outside torch 148, and which machine is shown in greater detail, although still in diagrammatic form, in FIG. 2. It will be noted that although the torches are shown one after the other along the casting line in FIG. 1b, they are in fact laterally displaced from each other relative to the casting line as more clearly shown in FIG. 2. It should be noted that while in FIG. 1b the cast strand 16 has not yet reached the torch machine, the illustration in FIG. 2 shows the strand 16 under the torch machine.

Referring now to FIG. 2, the torch machine is shown as having a frame 150, including members 152, 154, 156, 158, 160 and 162, cantilevered over the casting line from a side carriage 164 that rolls on a rail 166. The torch machine is prevented from falling across the course of the strand by means of a roller 168 attached to the torch machine and engaging a retainer rail 170. It should be appreciated that only fragments of the full length of rails 166 and 170 are shown.

Torches 146 and 148 are suitably suspended from the frame 150 for movement transversely of the course of the cast strand 16 as indicated by double ended arrows

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172 and 174. In order to impart to torch 146 such transverse or lateral movement in either direction, a traverse mechanism 176, secured to frame member 162, is coupled through a mechanical linkage 178 to that torch. Traverse mechanism 176 is controlled by the computer through a line 180. It should be understood that line 180 is symbolic of whatever number of lines connected to separate contact closure outputs of the computer are necessary to effect lateral movement of the torch 146 in either direction and at selected speeds (high or low).

A pulse generator PG2, secured to the frame 150 and driven by a wheel 184 in engagement with the mechanical linkage 178, generates a pulse for every unit of distance traversed by torch 146. The pulses are transmitted as process interrupts (CPI's) to the computer along a line 186.

In like manner, lateral movement in either direction is imparted to torch 148 through a link 188 by a traverse mechanism 190 attached to frame member 154, and controlled by the computer through a line 192 which line is symbolic of the necessary number of lines connected to separate contact closure outputs of the computer to effect computer control of lateral movement for torch 148 in either direction at a selected speed (high or low).

A pulse generator PG3 secured to frame 150 generates a pulse for every unit of torch distance traversed and transmits the pulses as process interrupts (CPI's) along a line 196 to the computer.

Vertical movement of torches 146 and 148 under control of the computer is effected by vertical drive units 200 and 202 respectively. Vertical drive unit 200 is controlled by the computer through a line 204, while drive unit 202 is controlled by the computer through a line 206. Each of lines 204 and 206 is of course symbolic of the necessary number of lines to separate contact closure outputs of the computer to effect up and down control for the torches.

The supply of cutting gases (example oxygen) and iron powder to torches 146 and 148 is controlled by control units 208 and 210, respectively. Control unit 208 is controlled by the computer for oxygen through a line 212, and for iron powder through a line 213, while control unit 210 is controlled by the computer for oxygen through a line 214, and for iron powder through a line 215.

A limit switch LS2 transmits a signal along a line 220 and through scanner 29 to the computer when the torch 146 reaches the edge 222 of the strand 16 during lateral traverse of the torch. In like manner a limit switch LS3 sends a signal to the computer along a line 224 through scanner 29 when torch 148 reaches the edge 226 of the strand 16 while the torch is executing a lateral traverse. Switches LS2 and LS3 are secured to frame member 158. The torch machine 144 is provided with a pair of tongs 228 for clamping it to the strand 16 whereby the torch machine is moved by and along with the strand. The tongs 228 are operated ON (clamped) or OFF (released) by a clamp control 230 in response to command by the computer along a line 232. Clamp control 230 is secured to frame member 158.

As has been noted, the torch machine 144 is moved downstream by the strand 16 when it is clamped to the strand. To move the torch machine upstream when it is unclamped from the strand 16, there is provided a return drive mechanism 240 including an endless chain 242 coupled to the torch machine carriage 164 and passing at opposite ends thereof over pulleys. Only one of the pulleys, a drive pulley 244, is shown. The drive pulley 244 is driven by a drive mechanism TMR controlled by the computer along a line 246. When the torch machine 144, while traveling upstream reaches a reference position marked by a limit switch LS4, the torch machine carriage 164 engages the limit switch LS4, whereby the switch transmits a signal to the computer along a line 248.

When the torch is returning upstream, a pulse is trans-

mitted to the computer for every unit distance traveled by the torch machine relative to the strand 16. These pulses are generated by a pulse generator PG4 driven by a measuring roll 250 which, when in a lowered position, engages the top of the strand 16. The measuring roll 250 is raised or lowered by a suitable vertical drive mechanism 252 in response to computer command along a line 254. Drive mechanism 252 is secured to frame member 158. Pulses from the generator PG4 are transmitted as process interrupts (CPI's) to the computer via a line 256. Downstream overtravel by the torch machine is registered by a limit switch LS5 (FIG. 1b) which transmits a signal (CCI) to the computer. A diagnostic line 259 connected to traverse driver 190 of the torch machine, is symbolic of a line connected to all control elements and drive units of the torch machine to communicate a diagnostic check (machine operable or inoperable) of the torch machine to the computer.

As seen in FIG. 1b, a crop chute 260 for receiving the crop separated from the strand is located between two of the rolls R.

Located along the casting line near its end (FIG. 1b) are a number of motor driven runout conveyor rolls RO1, RO2, RO3 and RO4. Each is driven by a separate roll drive unit controlled ON or OFF and speedup by the computer, at speeds which may be preselected at the operator's console 9. Since all the drive units are similar only one is shown at RD4 coupled to roll RO2. Drive unit RD4 is controlled ON or OFF by the computer through a line 262. Speedup control by the computer is through a line 264, and speed selection at the operator's console 9 is through a line 266.

The arrival of a cut slab at the end of the casting line is sensed by a sensor LS6 for example a limit switch which sends an interrupt signal to the computer to read the weight of the slab at that point which weight is sensed by a weight sensor SBW that generates signals representing weight and transmits them to the computer through scanner 26 and converter 27.

The computer 10 (FIG. 1b) conventionally includes an I/O unit (input-output unit) 270, a memory unit 272, an arithmetic unit 274, and a control unit 276.

The outputs of various sensors such as those for weight, temperature, flow rate, slag binder speed, oscillator rate, current and pressure, are analog in nature and before they are applied to the computer they are converted to digital form by the analog digital converter 27, to which the analog signals are sequentially applied by scanner 26 under control of the computer. More specifically, the output line of each of sensors TW1, TW2, ML, OS, SB, TS1, TS2, TS3, TS4, TS5, FM1, FM2, FM3, FM4, PS1, PS2 and SBW of each casting line A and B is connected as a separate input line to the scanner 26. The scanner, under command of the computer, periodically, for example every 1/2 second, and at a predetermined scan rate sequentially scans the lines from the various sensors. The scan rate may for example be 14 points in 10 ms. (milliseconds). The converted signals from the sensors are compared by the computer to reference values stored in the computer, and if they deviate beyond acceptable limits stored in the computer, the computer prints out and displays an alarm, so that the operator can make the necessary corrections at the operator's control console 9.

The outputs of the diagnostic lines from various controllers are CCI (contact closure inputs) to the computer and provide a diagnostic check for malfunction, for example: is the controller OFF or ON? These outputs are multiplexed before being applied to the computer. More specifically, each of the diagnostic lines 28, 32, 56, 58, 60, 62, 84, 102, 103, 105 and 259 is applied as a separate unit to the scanner 29 which periodically for example every 1/2 second, scans these lines at a predetermined scan rate under command of the computer to sequentially connect these lines to the computer. The scan rate

may for example be 14 points in 10 ms. Also connected as separate inputs to scanner 29 are the output lines of the switches and controllers POS, LS2, LS3. Certain contact closure outputs from the operator's console 9 are also connected as separate inputs to the scanner 29 to be included in the scan routine. The contact closure outputs of switches LS1, LS4, LS5, LS6 are applied directly as separate interrupts to the computer along CCI line 280.

The outputs of the pulse generators PG1, PG2, PG3 and PG4 are each applied as a separate interrupt to the computer via the CPI cable.

The output of a suitable reader such as card, tape or other, located for example at the operator's console 9, is applied to the computer input through a cable 282. Other outputs from the operator's control console are applied as necessary to the computer either as direct interrupts on a line 284 or multiplexed through a scanner 286 as necessary.

The computer has display and print out outputs 288 and 290 connected to suitable display elements and a printer located for example at the operator's control console 9. The computer is provided with a plurality of contact closure outputs (CCO's) connected to all the controllers and drive units (except LC and OR) so that the control functions of these various units commanded by the computer can be executed. Each of these contact closure outputs is connected to a different one of control lines 40, 42, 44, 46, 72, 76, 78, 80, 86, 92, 96, 98, 100, 108, 118, 124, 128, 142, 143, 180, 192, 204, 206, 212, 213, 214, 215, 232, 246, 254, 262 and 264 (all passing through the cable CCO). It is to be understood that in any case where any of the above lines represents a plurality of lines, each line of the plurality is connected to a different CCO.

Although operator's controls may be at several locations, for convenience of description, those of interest are all grouped at one location, the operator's control console 9. The control console includes the previously mentioned printer, display and reader. The console 9 also includes adjustable controls for entering slab width, thickness and desired length into the computer. Also located at the operator's console 9 are separate controls for adjusting each of the flow controls FC1, FC2, FC3 and FC4 whereby the operator can adjust the coolant flow rates at the different cooling zones. The console 9 further includes a separate control for adjusting each of the pressure controllers PR1, PR2 and PR3. Controls for adjusting the mold oscillator control OR and the mold lubricant rate control LC through lines 30 and 24 are also located in the operator's console 9.

The control console is further provided with controls for adjusting the output stoppers of tundishes TD1 and TD2 over lines 34 and 36. Speed selection controls for all the roll drive units in the system are located in the operator's console 9 to provide speed selection signals over lines 74, 94, 109 and 266. Additionally there is a control in the operator's console for operating the pinch roll set 20 in a reverse direction during the MOVE-IN mode. The control console is provided with mutually exclusive switches for selecting MOVE-IN, POUR, and MOVE-OUT modes, and for selecting either the outside torch or the inside torch or both torches of the torch machine. Each of these switches, in addition to providing control functions, also provides signals to the computer. Each mode switch when operated communicates with the computer as an interrupt, while each torch selector switch, when operated, transmits a signal to the computer through scanner 29.

Before the casting operation is started the following information is entered into the computer either through the operator's keyboard at the control console or through the reader: (A) various desired parameters together with upper and lower limits for (a) coolant flow rates for the different zones, (b) inlet and outlet coolant temperatures at zone 1, (c) strand skin temperatures at zones

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Z1, Z2 and Z3, (d) mold lube rate, (e) mold oscillation rate, (f) slab binder speed and (g) pressures for pinch roll sets 18 and 20; (B) desired crop cut length (for example one to twelve inches), desired slab length (for example thirteen to thirty feet); and (C) for the torch cutting program, preheat and torch cutting times and cutting distances (transverse). The front crop length should fit in the crop chute.

It is to be understood that the computer 10 is suitably programmed to execute the various monitoring and operating procedures described herein.

At the end of an immediately previous cast the casting line will have been left in the following condition: (a) all monitor operations deleted, (b) coolant in all zones turned off, (c) pinch roll set 18 locked, (d) all pinch roll sets open, (e) straightener roll 126 raised, and (f) pinch roll drives stopped.

The initial mode of the line is MOVE-IN mode during which the dummy bar is drawn to the mold from the dummy bar's home position so that the dummy bar head can be inserted into the bottom opening of the mold. To initiate this mode, the operator presses the MOVE-IN mode selector switch in the operator's control console 9.

Operation of the MOVE-IN mode switch transmits an interrupt CCI to the computer which responds by closing the contact closure outputs (CCO's) for effecting the following operations: close pinch roll sets 18 and 20; start the dummy bar winch 22 to pay out the dummy bar chain; turn off the coolant in zones Z1, Z2, Z3 and Z4; start the main drives in reverse. Also in response to the MOVE-IN mode CCI interrupt, the computer closes the contact closure outputs (CCO's), if not closed before, for effecting the following operations: (a) lower the dummy bar rocker arm to the conveyor roll level, (b) deenergize the straightener roll 126, (c) unlock the pinch roll set 18, (d) set pinch roll pressures to low, (e) deenergize dummy bar push off mechanism 140. In addition to the computer closing and opening contact closures to effect the above described operations, a redundant set of controls by-passing the computer is operated in response to the MOVE-IN mode switch to effect parallel control of the same operations and in the same manner. In other words, there are effectively two parallel paths for effecting the same operational controls, one through the computer, and the other directly in response to the MOVE-IN mode switch. The latter path may be considered a manual control path. Also in response to the MOVE-IN mode switch, all of the displays are cleared.

The rocker bar 110 having been lowered, the dummy bar head 114 hooked to the dummy bar chain 116 is passed through the wide opening below the raised straightening roller 126 and inserted between rolls 88 and 90 which, running in the reverse direction, propel the dummy bar head between the rolls of set 18 and through the guides of the casting line into the bottom opening (output) of the mold 14, at which time the pinch roll drives are stopped. Then, in the usual manner, suitable materials are packed in the space between the dummy bar head and the walls of the mold output opening to provide a seal against the molten metal that will be poured into the mold. That end of the dummy bar head that is inserted into the output opening of the mold is provided with projections around which the poured metal will solidify thus to "attach" the head of the cast strand to the dummy bar head.

When the above described sealing operation is completed, the operator depresses READY TO POUR switch at the operator's console 9. Operation of the READY TO POUR switch transmits a signal to the computer, which in response thereto runs a diagnostic checkup program that checks whether or not the following controls are operative or non-operative: lube control LC through line 28; oscillator control OR through line 32; coolant system through lines 56, 58, 60 and 62; pinch roll drives through lines 103 and 105; pinch roll pressure system through lines

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84 and 102; torch machine operations through line 259. If these devices and areas are functioning properly the computer will cause a READY TO POUR light to light up at the operator's console, signifying to the operator that he can start his casting operation. On the other hand, if there is a malfunction in any of these areas, the computer will print out a diagnostic message telling the operator that he should not start his cast because certain elements are malfunctioning. Before starting the cast the operator will move the speed controls on the operator's console 9 to the position which will provide, when the roll drivers are turned on, the desired withdrawal speed of the cast strand.

When the operator is ready to start the cast, he depresses the POUR mode switch at the operator's console, thus placing the system in the POUR mode. In response to this, the tundish TD1 through line 34 of the operator's console is "opened" allowing molten metal to pour into the mold 14. Also in response to the POUR mode switch being on, the computer effects the following: (1) calculates the front crop cut initiate point for the sequence control program, (2) clears the total strand length display on the operator's control console, (3) displays the preset slab length on the operator's control console, (4) turns on the roll drive units RD1, RD2, RD3, RD4 in the normal direction, (5) sets the pressure of pinch rolls 18 and 20 to HIGH through lines 78 and 100, and (6) turns on the cooling water for zone Z1.

The pinch roll set 20 drives the dummy bar chain 116 in the downstream direction to begin withdrawing the dummy bar head 114 from the mold, while the slack in the dummy bar chain is taken up by winch 22 under command of the computer through line 118.

As the strand 16 is withdrawn from the mold the pulse generator PG1 coupled to the pinch rolls 20 transmits an interrupt for every unit distance of strand cast, for example for every 1/4 inch of strand cast. A program in the computer which may be identified as the PG1 program runs each time an interrupt is received from the pulse generator PG1 and recognized by a main control program in the computer. In response to such interrupts received during an initial pre-determined short distance of strand cast, the computer starts to monitor the mold water temperature through sensors TS1 and TS2, starts to monitor the tundish weight through sensor TW1, initiates a data gathering program, and stores the start of cast time for a heat information sheet to be printed out.

Also in response to the PG1 interrupts the computer commands and causes to be executed the following groups of operations in the group order named:

(1) Just before the advancing strand 16 reaches zone Z2, start zone Z2 water flow by turning on FC2 through line 42, monitor zone Z1 temperature of strand through sensor TS3, monitor pinch roll current through current sensor CS, monitor pressure in pinch roll sets 18 and 20 through pressure sensors PS1 and PS2, monitor mold oscillation and lube rates and slag binder speed through sensors ML, OS and SB.

(2) Just before the advancing strand 16 reaches zone Z3, start the water flow for this zone by turning on FC3 through line 44.

(3) Just before the advancing strand 16 reaches zone Z4, start zone Z4 water flow by turning on FC4 through line 46; monitor zone Z2 strand temperature through TS4.

(4) Just before (about one foot before) the strand reaches pinch roll set 18, set these pinch rolls to low pressure through line 80; monitor zone Z3 strand temperature through TS5.

(5) Just before (about one foot ahead) the advancing strand reaches pinch roll set 20, decompress this pinch roll set to low pressure; start monitoring pressure of pinch roll set 18 through PSI.

(6) When the advancing dummy bar head 114 reaches

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the straightener roll 126, stop the dummy bar winch 22 through line 118 to provide slack in dummy bar.

(7) Then lower straightener roller 126 to force the dummy bar head 114 downward, thereby to release it from the dummy bar chain 116 and to straighten the course of the advancing strand 16.

(8) Just before the strand reaches the rocker bar 110, start monitoring pressure of pinch roll set 20; restart winch 22 through line 118 and raise rocker bar 110 through line 124 so that the advancing dummy bar and strand can pass under the rocker bar.

(9) When the advancing dummy bar head and strand reach the dummy bar push off mechanism 140, activate this mechanism through line 142 to push off (detach) the dummy bar head from the end of the strand 16. Mechanism, not shown, conveys the dummy bar head out of the way when it is pushed off the strand. If the dummy bar head is detached from the strand, it engages a limit switch POS, thus notifying the computer to run to completion the front crop cut program which is started in response to the strand 16 reaching the torch machine reference position marked by limit switch LS4. It should be noted that the front crop cut program will start only if the torch machine is at its reference position.

(10) When the preset crop cut point of the strand reaches the torch machine, clamp the torch machine to the strand 16 and lower the torches, and start moving the torches inward (toward each other) to the edges of the strand 16.

The torch control program in the computer includes the front crop cut program and utilizes the process interrupt inputs associated with the pulse generators PG2 and PG3. The control program receives a process interrupt from these pulse generators for every unit distance traversed by the torches, for example for every $\frac{1}{16}$ inch. By accumulating these interrupts the program knows exactly where the torches are during the cutting of the strand. It may be noted, that for the sake of simplicity the rollers R on which strand 16 travels, are not shown in FIG. 2, and that the torch machine carriage and rails are not shown in FIG. 1b.

In accordance with the torch control program in the computer, the following described crop cut and subsequent slab cuts and associated routines of the torch machine are effected under computer command. The torches are initially at respective reference outward positions (home bases of the torches). When the advancing strand 16 reaches the proper position to effect a crop cut of the selected crop length entered in the computer, on command from the computer, through lines 232, 180, 192, 204 and 206, the torch machine clamps to the strand and the torches start lowering and traversing toward each other inwards to the opposite edges 222 and 226 of the strand. When they hit the limit switches LS2 and LS3 positioned at the strand edges, the computer in response to the signals from the limit switches stops the movement of the torches, and the torches preheat the strand edges 222 and 226 with their heating gases for a predetermined length of time previously programmed into the computer. Then, when the preheat time has expired, the cutting oxygen is turned on and the torches begin notching the strand. For the crop cut, the iron powder is turned on with the oxygen. The notching operation is done at a slow traverse speed for a programmed period of time and when this time has expired, the torches start cutting the strand at high traverse speed. When both torches are used, and when the torches come within a predetermined distance, for example two inches, of each other, the inside torch 146 will raise and return to its initial base. When the inside torch 146 completes its cutting, raises and returns, the outside torch 148 stops cutting and stays in position with only its heating gases on. The control program in the computer then calculates the point along the casting line at which the outside torch should restart and complete the final two inches of cut by the time the

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crop end reaches the crop chute 260 so that the cropped end will fall into the crop chute. When the calculated restart point is reached, computer commands restart the cutting action (oxygen on traverse) of the torch 148. If a flameout occurs during the front crop cut, the operator signals the computer through the console 9, and under computer command, the remaining torch cuts to within a predetermined distance for example six inches of the point where the malfunction occurred. This six inches will then be cut by hand at the end of the casting line at a piler located thereat. If the dummy bar head had not separated from the strand 16 at the dummy bar push-off station, the computer is so "notified" by lack of signal from POS, and the front crop cut would not have been completed, since the crop with the dummy bar head attached could not drop into the chute 260. In that case the front crop cut would have stopped six inches before completion, and the balance of the cut finished by hand at the end of the casting line.

At the strand position where the crop cut is completed by the torches, the torches are returned to their respective home bases, and the computer knowing the positions of the torches and the strand at all times, commands the drive unit 252 to lower the measuring roller 250 to the surface of the strand and, again under computer command, the tongs 228 are released by the clamp control 230, and, when relative motion between the strand 16 and the torch machine 144 is not zero, the torch machine starts returning under command of the computer to the point on the strand where the next slab cut should occur in accordance with the instructions on slab length programmed into the computer. On its return journey upstream, the position of the torch cutting machine relative to the strand 16 is known by the computer by reason of the interrupts supplied by the pulse generator PG4 to the computer. These interrupts are generated for every unit distance of relative travel, for example for every one eighth of an inch of travel. When the torch machine reaches the point where the next slab cut should occur, on command from the computer, the tongs 228 are operated to clamp the torch machine to the strand 16, and the torches start lowering and traversing inwards to the edges of the strand. When the torches hit the limit switches LS2 and LS3, the torches under computer command stop and preheat the slab edges with their heating gases for the programmed time. When the preheat time expires, the cutting oxygen is turned on and the torches begin notching the slab. The notching operation is done at slow traverse speed for a programmed time period and when this time expires, the torches start cutting the strand at high traverse speed. When both torches are used, the torch 146 will raise and return to its initial base, a predetermined distance for example two inches prior to meeting the outside torch 148, and the latter torch will complete the slab cut. When torch 148 has a predetermined distance for example one inch of slab left to cut, the computer increases the speed of the runout rolls RO1, RO2, RO3 and RO4 through control line 264 to pull the slab away from the strand when the final inch is cut. When the cut is complete, the oxygen is cut off, the torches are retracted and the measuring roller 250 is lowered; the tongs 228 are released, and as soon as there is relative motion between the strand and the torch machine, the torch carriage starts returning to the point where the next slab cut will occur. This routine is repeated for every slab cut. If at any time a flameout occurs in one of the torches, the operator designates which torch is operable by manipulating the torch selector switches at the operator's control console 9. When the computer receives the information that only one torch is operable, it calculates a new cut-complete-point for the remaining torch, utilizing the distance that the malfunctioning torch had traversed, and the "good" torch will then traverse the remaining distance required to cut the slab. When each cut slab reaches the position along the casting line identified with the limit switch LS6, this switch

notifies the computer, and the weight of the slab as sensed by the weight sensor SBW is transmitted to the computer through the scanner 26. At the end of the casting line the slabs are discharged onto a piler for piling in a desired manner.

It should be noted that the computer is programmed to begin the cutting of the strand at a point along the casting line such that the cutting operation will be completed before the torch machine engages the overtravel limit switch LS5, and the last one inch of cut will be made with the end of the strand on at least one of the runout rolls RO1, RO2, RO3 and RO4 whereby the runout rolls can be speeded up by the computer to pull the severed slab away from the strand.

At this point, it should be emphasized that, except for the operator's signal in case of flameout, all the preceding operations of the torch machine and its elements such as the torches and clamping tongs, are effected in response to computer commands in accordance with programs and instructions preset into the computer.

From the displays at the operator's console, the operator is always aware of the amount of molten metal left in the tundish TD1. When the tundish runs out of molten metal, the operator selects the MOVE OUT mode switch on the operator's console 24 to place the system in the MOVE OUT mode. In response to operation of this switch, the casting line is stopped for a predetermined period of time, for example five minutes, to allow the tail end of the strand to cool and solidify before it is withdrawn from the mold (under command of the computer). After the solidifying time period (five minutes) runs out, and under further command of the computer, the following operations are effected:

(1) When the strand leaves the mold the monitoring operations for mold coolant flow, mold coolant temperature (zone Z1), mold oscillation, mold lube rate, slab binder rate, and strand temperature for zone Z1, are deleted.

(2) When the tail of the strand leaves zone Z1, coolant flow for zone Z1 is stopped; monitor of zone Z2 coolant flow is deleted.

(3) When the tail of the strand leaves zone Z2, coolant flow in zone Z2 is stopped; monitors for zone Z3 coolant flow and strand temperature for zone Z2 are deleted.

(4) When the strand tail leaves zone Z3, coolant flow for zone Z3 is stopped; monitors for strand temperature monitor for zone Z3 and coolant flow for zone Z4 are deleted.

(5) When the strand tail leaves zone Z4, coolant flow for zone Z4 is stopped.

(6) Pinch roll set 18 is locked before the tail reaches this roll set in order to keep the tail from curling.

(7) After strand tail passes through pinch roll set 18, this roll set is opened; monitors for pinch roll set 20 current and pressure of pinch roll sets 18 and 20 are deleted.

(8) After strand tail passes through pinch roll set 20, the pinch roll set 18 is unlocked; pinch roll set 20 is opened; straightener roll 126 is raised, and pinch roll drives RD1 and RD2 are stopped.

In the meantime the torch cutting machine is operating as hereinbefore described, cutting the strand in slabs of programmed predetermined length.

During all its monitor assignments, as the cast is progressing, the computer compares the sensed values of the various parameters, being monitored and determines whether they are within or without predetermined stored limits. When a sample parameter is outside permissible limits, the computer through the printer at the operator's console prints out alarms so that the operator can correct particular out of limits area by adjusting the proper controls at console 9. This is applicable to the mold oscillation rate, the mold lube rate, the slab binder speed, the coolant temperature in zone Z1, the coolant flow rates in zones Z1, Z2, Z3 and Z4, the strand temperatures in zones Z1, Z2 and Z3, the low pressure of pinch roll sets 18

and 20, the current of roll drive RD2, and the slab weights at the end of the casting line.

During the course of the cast, an INFORMATION SHEET program in the computer is responsible for gathering information relative to the strand being cast and the computer will retain this data in its memory until the casting is complete. After the cast is finished the information obtained is printed out. The INFORMATION SHEET program, obtains information as a function of position and time with respect to the strand. Position of the strand is reflected by information retained in the memory for the information sheet until the cast reaches a predetermined point on the strand. Time is reflected as a variable to position, so that each piece of information can be stored a given period of time after the cast reaches the specified point. The program starts gathering data at some time after the strand reaches zone Z3. The information obtained at this time is pinch roll current, pinch roll pressure (high) and time. After the strand reaches the pinch rolls, data is gathered at specified intervals relating to casting line speed, mold lube rate, mold oscillation rate, slab binder speed, zone Z1 coolant temperature and flow rate, flow rates of zones Z2, Z3 and Z4, pinch roll pressure (low), strand temperature zones Z1, Z2 and Z3, and the time associated with each reading is stored.

As a cast is progressing, and slabs are being cut and weighed, the computer is storing the slab length and weight for every slab to be recorded in the information sheet. When all strands cast have been cut and weighed, the information sheet is printed out, although the operator may at any time on demand order a printout. Prior to the actual printout of the information sheet data, the computer program makes the following computations: total strand length from the pulse generator interrupts; total strand weight which is the unit weight of the metal (pounds/inch); total slab lengths cast for the strand; total heat weight cast for the strand; total slab weight cast for the strand; percent yield = total slab weight ÷ total heat weight × 100; mold lube rate in fluid ounces per minutes; and mold oscillations in cycles per inch strand travel.

The computer is programmed to display to the operator at the console 9 how many slabs of predetermined length have been poured from the ladle into the tundish. This program computes the number of slabs cast from the tundish and adds to this the number of slabs represented by the metal now in the tundish, and updates the display to the value when another predetermined fraction of a length of a slab has been poured. The computer maintains in storage a record of the length of the strand cast and from this it calculates the number of predetermined length slabs in the already cast strand. The predetermined length of the slabs has been previously preset into the computer by the operator. The computer maintains a periodic check of the metal weight in the tundish and from this it calculates the number of slabs represented by the weight noted, utilizing preset constants and information regarding weight per unit length of strand preset or programmed into the computer by the operator.

The computer is programmed to allow the operator to obtain the information associated with the next strand to be cast on a demand basis, except during MOVE OUT mode. The data groups gathered for such a demand log are:

- (1) Pinch roll current, pinch roll pressure (high).
- (2) Mold lube, mold oscillation, slab binder rates, and line speed.
- (3) Zone Z1 coolant flow rate and temperatures (in and out).
- (4) Coolant flow rates zones Z2, Z3 and Z4.
- (5) Pinch roll pressure (low).
- (6) Strand temperature zone Z1.
- (7) Strand temperature zone Z2.
- (8) Strand temperature zone Z3.

(9) Preset slab length, date, heat and specification numbers.

It should be understood that the operator's control console 9 includes a duplicate set of controls and adjustments for casting line B, and that there is a duplicate set of interconnections between the various elements of the casting line, the computer and the operator's control console, for casting line B, whereby computer 10 controls both casting lines A and B simultaneously in the manner heretofore described for casting line A. In so doing, the computer executes on a "first-come first-served" basis, equal priority bids from casting lines A and B.

It should be understood that the herein described arrangements are simply illustrative of the principles of the invention, and other embodiments and applications are within the spirit and scope of the invention.

I claim as my invention:

1. In a continuous casting system having a casting line which line includes a mold at the beginning of the line and a plurality of types of controllable devices successively disposed along the line for acting on the cast product, from which mold the cast product is advanced along the line to be affected by said devices, control apparatus comprising means for generating digital information while the cast product is advancing each of successive predetermined increments of the length cast, a computer, a control circuit connected between each device and the computer for controlling the device in response to control signals from the computer, means for feeding said digital information to said computer, the computer being operable to accumulate said digital information as it is received and to keep track of the linear position of the cast product as it progresses along the casting line, said computer being responsive to accumulations of said digital information signifying the arrival of said cast product at each of successive positions along said line to apply a control signal to a different one of said control circuits in predetermined order, at least one of said devices being a pinch roll set that is adjustable for at least tending to change roll position.

2. The combination of claim 1 wherein another of said devices is a coolant flow control device.

3. The combination as in claim 1 wherein one of said control signals is applied to the control circuit of the pinch roll set to change roll pressure.

4. The combination as in claim 1 wherein one of said control signals is applied to the control circuit of the pinch roll set to change it from one to the other of open and closed positions.

5. The combination as in claim 4 wherein one of said control signals is applied to the control circuit of the pinch roll set to lock the set in closed position.

6. The combination as in claim 1 wherein said pinch roll set is driven by a drive unit, and one of said control signals is applied to control said drive unit from one to the other of ON and OFF states.

7. The combination as in claim 1 wherein one of said devices is a straightener roll, and one of said control signals is applied to the control circuit of the straightener roll to change its distance from the casting line.

8. The combination as in claim 1 wherein one of said devices is a dummy bar rocker arm retracting means.

9. The combination as in claim 1 wherein one of said devices is a dummy bar head push-off means.

10. The combination as in claim 1 wherein said devices include in the order named, coolant flow control means, said pinch roll set, a straightener roll, dummy bar retraction means, dummy bar head push-off means and cutting means for cutting the cast product in desired lengths.

11. The combination as in claim 1 wherein another of said devices is a cutting means for cutting the cast product into desired lengths.

12. The combination as in claim 11 which further includes a motorized run out roll that is speeded up by the computer when the cutting means has effected a cut of pre-

determined depth whereby the severed length of the cast product is separated from the parent cast product by the run out roll.

13. The combination as in claim 11 wherein in either direction and comprises

- (A) said cutting means is movable along said line
 - (a) means operable under command of the computer for moving said cutting means upstream;
 - (b) clamping means operable under command of the computer for clamping the cutting means to the strand whereby the cutting means moves downstream along with the strand;
 - (c) a pair of cutting elements operable under command of the computer for cutting the strand from opposite sides thereof, the movement of the cutting elements during the cutting operation being toward each other in a direction transversely of the strand;
 - (d) means responsive to movement of the cutting elements for transmitting to the computer information relating to position of the cutting elements; and
 - (e) means responsive to upstream movement of the cutting means relative to the strand for transmitting to the computer, position data on the cutting means relative to the strand; and

(B) said computer is arranged to effect control of said cutting means to perform the following operations:

- (1) clamp the cutting means to the strand at the proper point along the length of the strand such that the cutting operation will be completed at a predetermined point along the processing line;
- (2) start the cutting elements traversing toward each other to cut into the strand from opposite sides thereof;
- (3) stop one of the cutting elements when the cutting elements come within a predetermined distance of each other and complete the cut with the other cutting element;
- (4) when the cut is complete, retract the cutting elements and unclamp the cutting means from the strand; and
- (5) move the cutting means upstream and clamp it in the strand at the proper point to effect a desired cut by the time the strand reaches a predetermined point along said line.

14. In apparatus for cutting an elongated metal strand while in motion along a processing line,

(A) a computer;

(B) cutting means disposed along said line and movable therealong in either direction, said cutting means comprising

- (a) means operable under command of the computer for moving said cutting means upstream;
- (b) clamping means operable under command of the computer for clamping the cutting means to the strand whereby the cutting means moves downstream along with the strand;
- (c) a pair of cutting elements operable under command of the computer for cutting the strand from opposite sides thereof, the movement of the cutting elements during the cutting operation being toward each other in a direction transversely of the strand;
- (d) means responsive to movement of the cutting elements for transmitting to the computer information relating to position of the cutting elements; and
- (e) means responsive to upstream movement of the cutting means relative to the strand for transmitting to the computer, position data on the cutting means relative to the strand;

(C) said computer being programmed for effecting control of said cutting means to perform the following operations:

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- (1) clamp the cutting means to the strand at the proper point along the length of the strand such that the cutting operation will be completed at a predetermined point along the processing line;
- (2) start the cutting elements traversing toward each other to cut into the strand from opposite sides thereof;
- (3) stop one of the cutting elements when the cutting elements come within a predetermined distance of each other and complete the cut with the other cutting element;
- (4) when the cut is complete, retract the cutting elements and unclamp the cutting means from the strand; and
- (5) move the cutting means upstream and clamp it to the strand at the proper point to effect a desired cut by the time the strand reaches a predetermined point along said line.

15. The combination as in claim 1 wherein said digital information is a pulse for each of successive predetermined equal increments of advance of the cast product.

16. The combination of claim 15 wherein

- (A) one of said devices is cutting means for cutting the the cast product while in motion along the casting line, which cutting means is disposed along said line and movable therealong in either direction, said cutting means comprising
 - (a) clamping means operable under command of the computer for clamping the cutting means to the cast product whereby the cutting means moves downstream along with the cast product;
 - (b) a pair of cutting elements operable under command of the computer for cutting the cast product from opposite sides thereof, the movement of the cutting elements during the cutting operation being toward each other in a direction transversely of the cast product;
 - (c) means responsive to movement of the cutting elements for transmitting to the computer information relating to position of the cutting elements; and
 - (d) means responsive to upstream movement of the cutting means relative to the cast product for transmitting to the computer, position data

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on the cutting means relative to the cast product;

- (B) means operable under command of the computer for moving said cutting means upstream; and
- (C) said computer is arranged to effect control of said cutting means to perform the following operations:
 - (1) clamp the cutting means to the cast product at the proper point along the length of the strand such that the cutting operation will be completed at a predetermined point along the casting line;
 - (2) start the cutting elements traversing toward each other to cut into the cast product from opposite sides thereof;
 - (3) stop one of the cutting elements when the cutting elements come within a predetermined distance of each other and complete the cut with the other cutting element;
 - (4) when the cut is complete, retract the cutting elements and unclamp the cutting means from the cast product; and
 - (5) move the cutting means upstream and clamp it to the cast product at the proper point to effect a desired cut by the time the cast product reaches a predetermined point along said line.

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R. SPENCER ANNEAR, Primary Examiner

U.S. Cl. X.R.

164—263, 283; 266—23 M

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,614,978 Dated October 26, 1971

Inventor(s) M. A. Kosco

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 15, line 25, after "advancing", insert
-- representing --;

Column 16, cancel line 5;

Column 16, line 6, after "line", insert
-- in either direction and comprises --;

Column 17, line 23, cancel "the".

Signed and sealed this 13th day of June 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents