United States Patent

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[54] START-UP SYSTEM FOR CONTINUOUS CASTING MOLD

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[52] **U.S. Cl.**.....**164/154,** 164/82, 164/282

[51] **Int. Cl.**.....**B22d 17/32,** B22d 11/08

[58] **Field of Search**.....164/4, 82, 154, 155, 282

[56] **References Cited**

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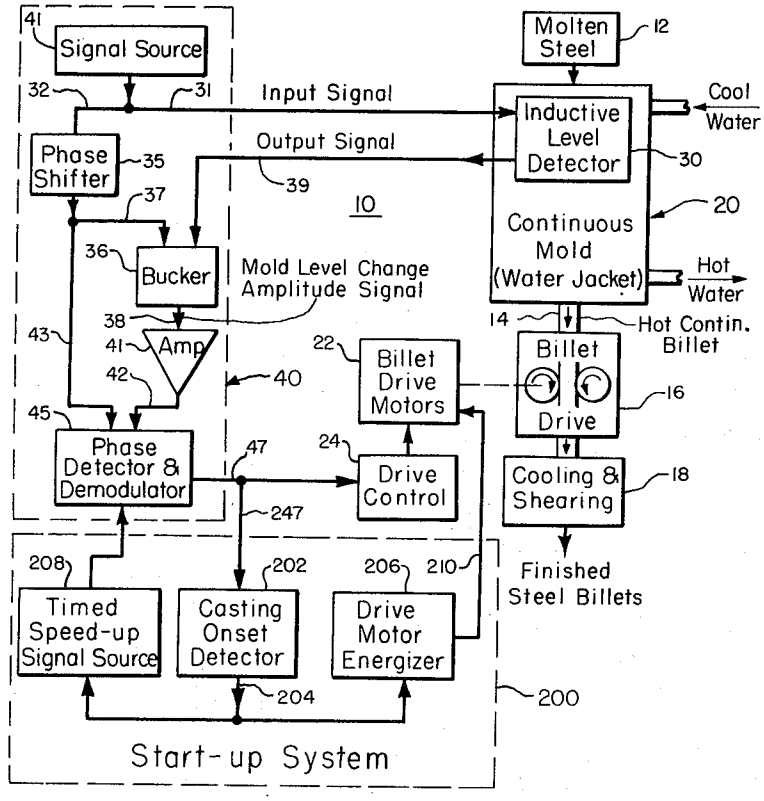
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[57] **ABSTRACT**

A start-up system for a continuous casting mold level control system which uses the control signal to detect the onset of casting and in response thereto, energizes the drive motors and alters, for an initial predetermined short period, the control signal fed to the drive motor controls to speed up the withdrawal of continuous billet for that period. Thereafter it automatically restores the control system to normal operation.

9 Claims, 4 Drawing Figures



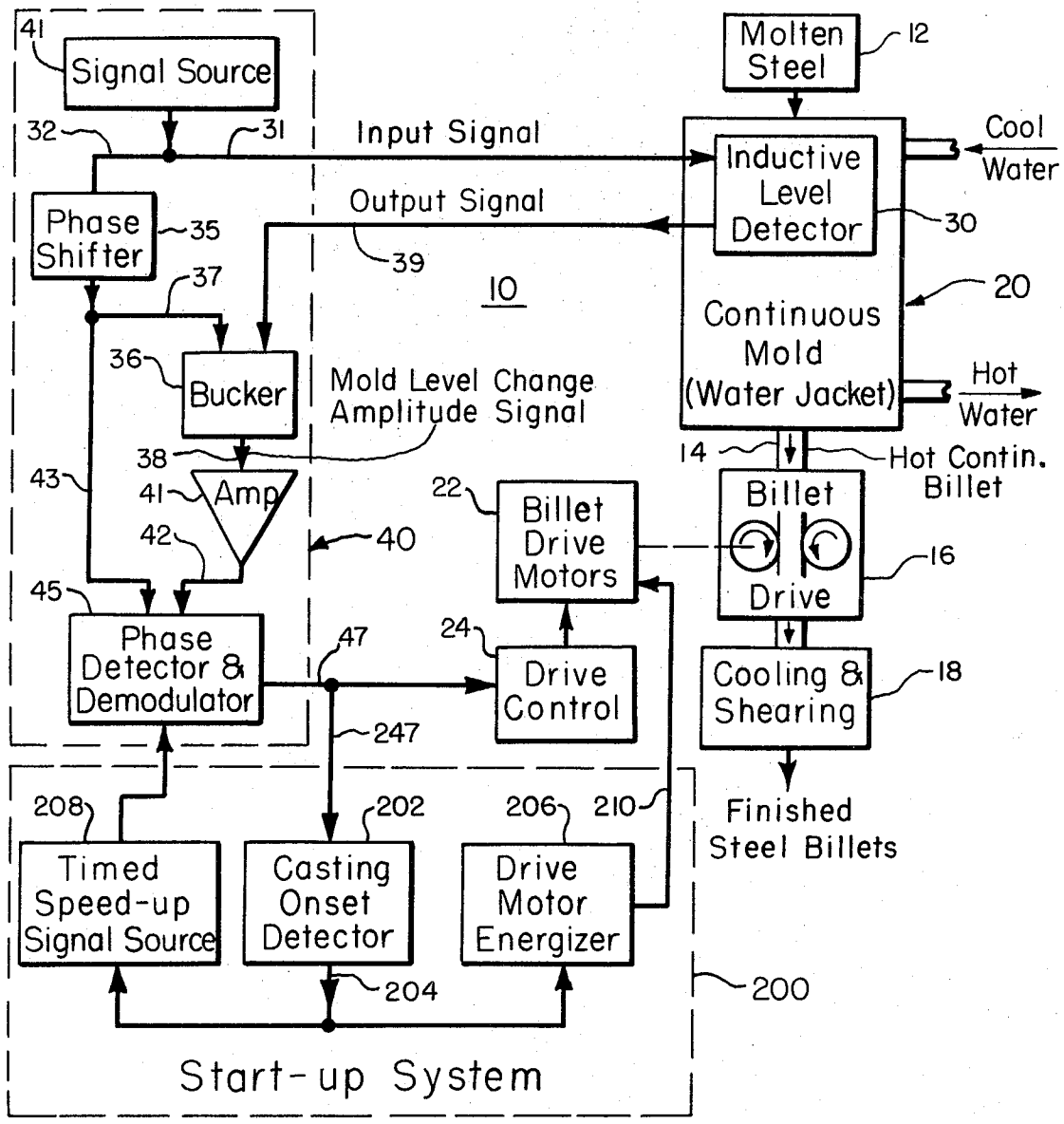


FIG. 1

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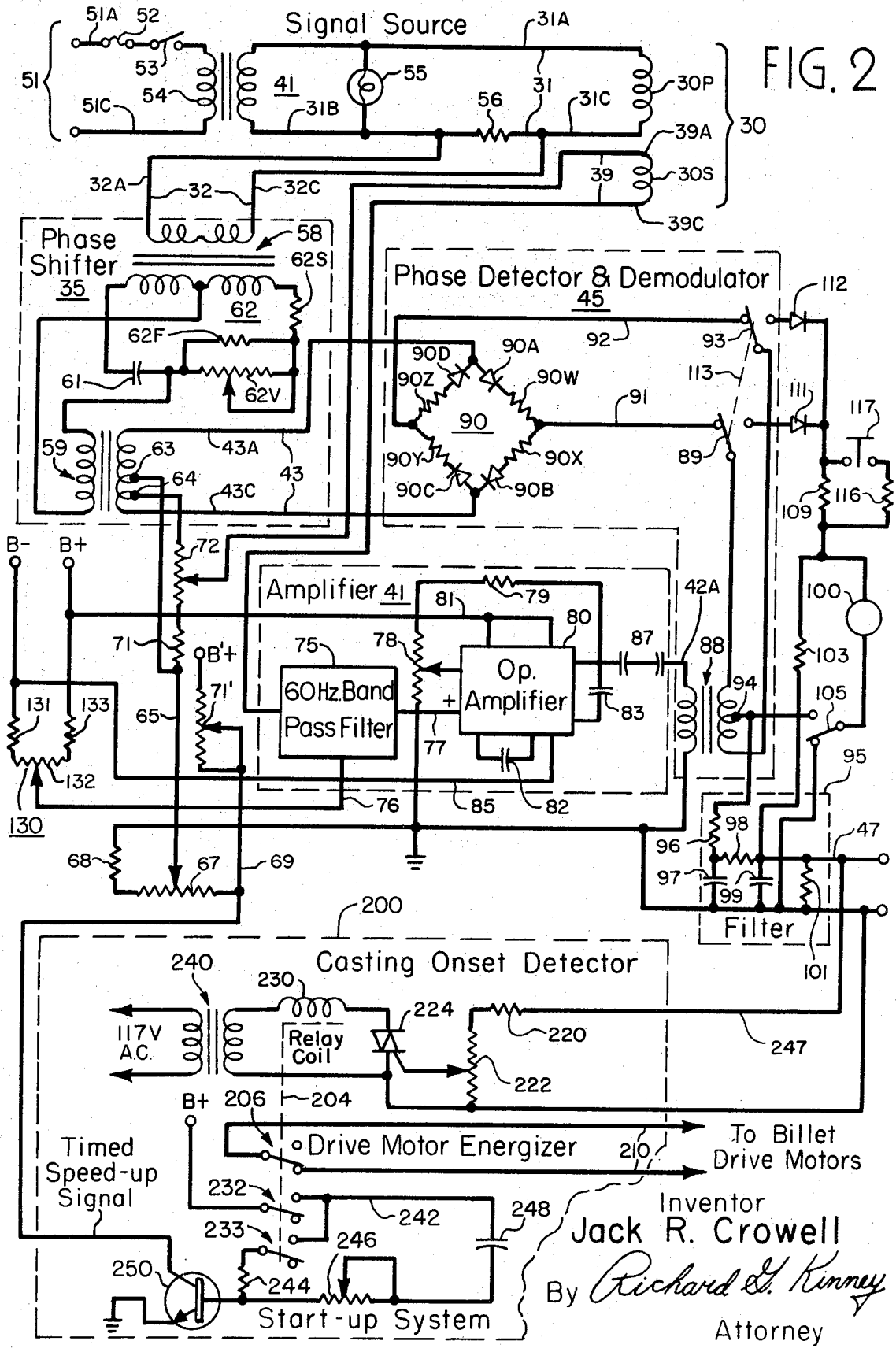

Signal Source
Phase Shifter
35
Phase Detector & Demodulator
45
Amplifier 41
60 Hz. Band Pass Filter
Op. Amplifier
Filter
Casting Onset Detector
117V A.C.
Relay Coil
Drive Motor Energizer
To Billet Drive Motors
Timed Speed-up Signal
Start-up System
B-
B+
B'+
51
51A
52
53
54
51C
41
31A
31
31B
31C
55
56
30
30P
30S
39A
39
39C
32
32A
32C
58
62S
62
62F
62V
61
59
63
64
43
43A
43C
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71'
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133
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90A
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90C
90D
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90Y
90Z
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99
100
101
103
105
109
111
112
113
116
117
42A
47
200
240
230
224
220
222
247
204
206
210
232
233
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248
250
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FIG. 2

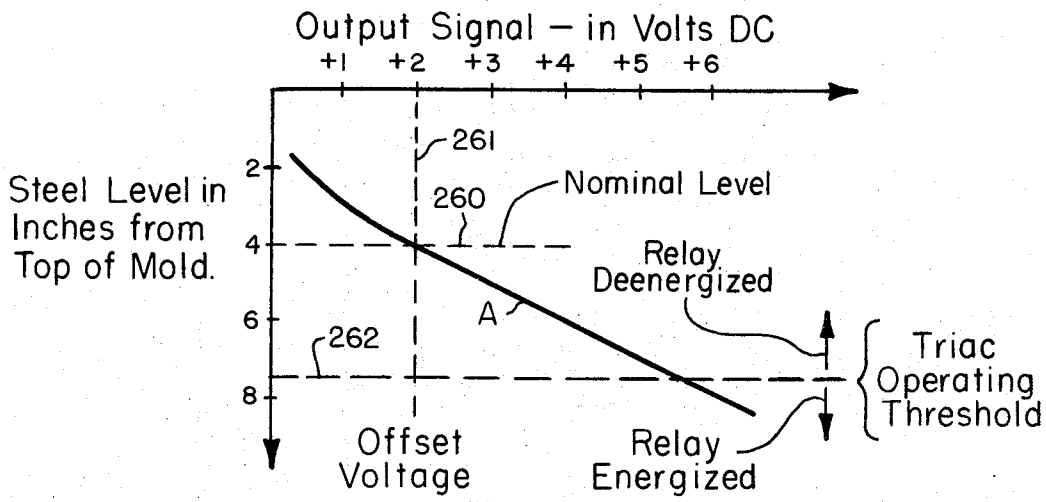


FIG. 3

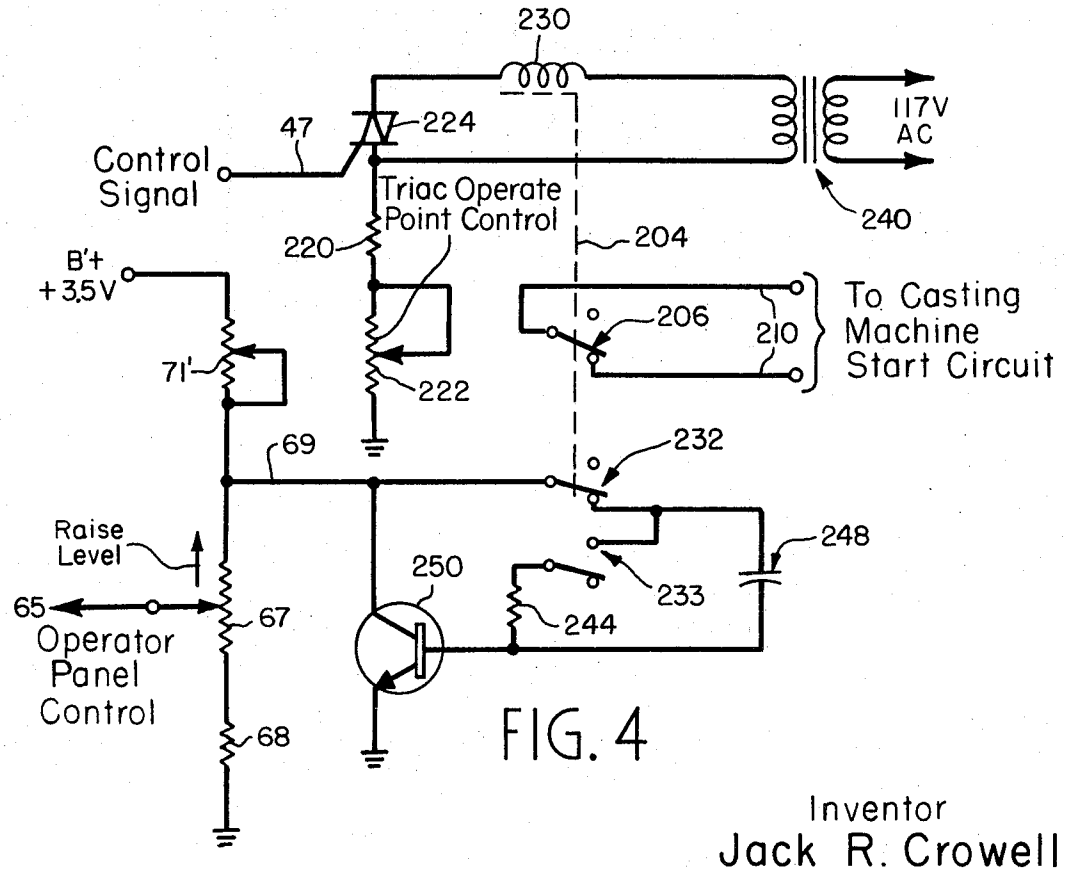


FIG. 4

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START-UP SYSTEM FOR CONTINUOUS CASTING MOLD

FIELD OF THE INVENTION

The present invention relates to a control system for a continuous casting system. More specifically, the present invention relates to a start-up system for detecting and controlling the onset of casting and altering the control system of a continuous casting machine of the type used for producing a continuous billet of steel from molten steel.

BACKGROUND OF THE INVENTION

In one commercial important process of continuously casting steel, a stream of molten metal is poured from a tundish box into a water-cooled mold. The steel is cooled sufficiently within the mold that it may be withdrawn as continuous billet. The level of molten steel in the mold is determined by the rate of flow of the molten steel from the tundish and the rate of withdrawal of cast billet by a drive system. The present invention concerns improved start-up system in this environment. The position that a continuous casting machine bay occupy in one particular steel mill is noted in the article entitled "Steel" by D. R. G. Davies in the McGraw-Hill Yearbook of Science and Technology (1969) at page 325.

Basically, a continuous casting mold functions to take liquid molten steel and to transform it into a continuous billet of steel by passing it through a water-cooled mold that forms it and cools its outer surface to a solid state. Thereafter, the continuous billet is further cooled and cut or sheared into individual steel billets. For a general source on continuous steel castings, reference could be had to the works: "The Continuous Casting of Steel in Commercial Use" by K. P. Korothov, H. P. Mayorov, A. A. Skvortsov and A. D. Akimenko translated by V. Alford; "Continuous Casting of Steel" by M. C. Boichenko (1957) translated by L. Herdan and R. Sewell; and "Continuous Casting" D. L. McBride in the Proceeding of Technical sections of the Iron and Steel Division of the Metallurgical Society of the American Institute of Mining, Metallurgy and Petroleum Engineers (autumn, 1961).

It should be readily apparent that the working of such a product as molten steel is both extremely dangerous and difficult. In the case of forming it into continuous billet by the continuous casting method, it is desirable to maintain the level of molten steel in the casting machine within fairly close tolerances. If the level is maintained too high as by pouring excessive amounts of steel in the machine, it may splash over causing loss of steel, perhaps damage to equipment and possibly danger to the human operators. In addition, if the molten steel is too low in the mold it may have insufficient exposure to the cooling walls to solidify, again resulting in "-breakout". This can occur at a point somewhat below the end of the mold as the continuous billet normally is hardened or solidified only at its outer surface and contains a molten core. Also if the steel is extracted too slowly or remains in the mold too long, the steel may harden too much making it difficult to handle in later stages or, in an extreme case, solidifying within the mold itself. To overcome the tendency of the molten steel to adhere to the sides of the mold or form, it is the normal practice to both add a lubricant, a special oil, at the top of the mold and to oscillate the mold fairly rapidly in the vertical direction. This rapid up-and-down movement, although improving the overall system, makes the problem of detecting and controlling mold level height more difficult.

The importance of maintaining a proper level in the mold has not been overlooked by those familiar with this industry. Complicated devices and complex and expensive machinery have been employed to detect and maintain the proper level. One presently used commercial mold level indicator and control uses a radioactive source such as cesium **137** sealed in a stainless steel capsule which is **1,000** metal for radiation shielding and, which in turn, is housed in a steel cabinet to protect the Mallory metal from molten steel splash-over damage. This source is positioned adjacent to but spaced from the mold, on one side thereof, to direct a beam of radioactive

particles through the mold mechanism, its water jacket, the molding core itself, and any molten steel therein. A solenoid operated shutter mechanism is movably provided to interrupt the radiation beam, to provide safe access for the operating personnel around the radioactive source. The radiation is picked up by a detection unit comprising a solid state high-sensitivity radiation detector of the scintillation type enclosed in a separate water-cooled steel housing positioned outside of but adjacent to and spaced from the mold unit on the opposite side from the source. Normally, two detection units are employed for monitoring molten steel levels, one for normal operation and one for start-up. The signal from the detector is used to vary the rate of speed of the drive mechanism that removes the continuous billet from the steel casting mold.

Despite the shielding and precautions taken with this radioactive source, it has often proved to be unable to withstand the extreme environment in which it is used. It has been the experience of those practicing this steel making process that the occasional and unavoidable spills and splashes of molten steel have caused the radioactive detecting units to fail or be taken out of operation for repairs for extended periods of time. It has been found to be both expensive and time consuming to attempt to repair and maintain in operable condition such units.

When the units are disabled, the most widely employed alternative is human supervision. That is, a worker or operator in protective clothing and shielding is detailed to physically inspect the continuously changing levels of molten steel in the continuous casting machines and to vary the flow of steel to the machine and from machine, based upon his human judgement and vision. Needless to say, this environment, which is extreme for a shielded radioactive detecting system, is far from ideal for the human worker detailed to such a task. Indeed, it is not surprising to find that these workers often make errors in judgment resulting in less than optimum performance and malfunctioning of the continuous casting machinery.

For normal operating condition the system described in the co-pending application for United States Letters Patents, entitled "Continuous Casting Mold Level Control," Ser. No. 3,421, filed Jan. 16, 1970, in the names of Jack R. Crowell, the present inventor, James R. Tomashek and Donald H. Ward, and which is assigned to the assignee of the present invention, meets many of the disadvantages of previous systems and provides an effective and efficient automatic control system for use in this extreme environment. While that system is entirely satisfactory for normal operation the present invention is concerned with the start-up of such a system without direct human supervision or observation. It has been found that when start-up occurs and casting begins that the response of the system is initially too slow and that at the on set of casting, over-spill of molten steel can occur. It is believed that the cause of this is related to the fact that the mold components have not yet reached their normal operating temperatures.

SUMMARY OF THE INVENTION

A start-up system for a continuous casting mold constructed in accordance with the present invention includes means for detecting the on set of casting and for producing a signal representative thereof. Also provided are means for energizing the billet drive system in response thereto and means coupled to the casting on set detector for altering the speed control signal for a predetermined initial period in response to the signal and for automatically restoring that signal to its normal operation after that period.

The present start-up system eliminates the necessity of a separate start-up detector at the mold, such as that employed in the above mentioned radioactive detection and control system, and instead uses the same inductive level detector for both normal operation and start-up.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 is a block diagram illustrating a mold level detection and control system including a start-up system in accordance with the principles of the present invention;

FIG. 2 is a circuit diagram of the system of FIG. 1;

FIG. 3 is a graphical representative of the relationship between the control signal and the level of molten metal in the mold, which graph is useful for illustrating the operation of the system and circuit of FIGS. 1 and 2; and

FIG. 4 is a circuit diagram of a modification of the start-up circuit portion of the circuit of FIG. 2.

DETAILED DESCRIPTION

Referring to FIG. 1 there is depicted a steel billet continuous casting system generally designated **10** which is constructed in accordance with the principles of the present invention. The system **10** functions to transform molten steel into steel billet. A molten steel source **12** (which may be an electric-arc furnace feeding a tundish) feeds molten steel to a continuous casting mold, generally designated **20**, from which it emerges as a continuous hot billet **14** which is advanced therefrom by a drive **16**. The billet **14** is more fully cooled and sheared into billets at a later station **18**. For cooling the molten steel, the mold **20** is provided with a water jacket into which relatively cold water is pumped and from which relatively hot water extracted during the casting process.

The billet drive **16** is driven by drive motors **22** which are controlled from a drive control unit **24** in a manner that allows the speed that the system **16** drives the billet **14** to be varied over a range of speeds. As the rate of molten steel from the source **12** is reasonably constant and not subject to fine control the speed of the drive **16** is the primary determiner of steel flow through the mold **20** during normal operation.

An inductive level-detector, generally designated **30**, is provided as a part of the mold unit **20** and a drive control signal circuit, generally designated **40**, is also provided.

The circuit **40** comprises an ac signal source **41**, which may be the conventional **60** cycle power lines or some other frequency signal source which is either higher or lower in frequency. This source **41** is coupled, as indicated by line **31**, to the level-detector **30** and, as indicated by line **32**, to the phase shifting circuit **35**. The output of the phase shifting circuit **35** is fed to a bucking circuit **36** as indicated by line **37**. The output of the level detector is fed to the bucking circuit as indicated by line **39**. The combined output from the detector **30** and circuit **35** is preferably nulled or balanced by circuit **36** to be zero at desired height or level of the molten steel within the mold **20**. Thus, whenever output is fed over the line **38**, it is representative of the shift in the output signal resulting from a change of the level in the continuous mold **20**. This output **38** is amplified by a conventional amplifier **41** and fed, as indicated by line **42**, to a phase detector and demodulator **45**. The output from the phase shifter **35** is also fed, as signified by line **43**, to the phase detector and demodulator **45** wherein the relative phase between the outputs on line **43** and **42** are compared and detected and a demodulated dc signal, is produced on the output line **47** and fed to the drive control **24**.

The output on line **47** is preferably a dc voltage whose change in amplitude from a nominal voltage level represents the magnitude of change of height of the molten steel in the continuous mold **20** and also whose direction of change (plus or minus), from that nominal level, represents the direction of change in steel height (up or down). This signal is fed, as symbolized by the line **47**, to the drive control unit **24** which in turn controls the drive motors **22** to alter the speed of withdrawal of the hot billet **14** from the mold so as to bring the level of molten steel therein back to the desired level.

So far, the normal operating portion of the system **10** has been described. As mentioned above, however, certain problems are encountered during the start-up of the system and, therefore, in accordance with the present invention, further included in FIG. **1** is a start-up system which is generally designated by the numeral **200**.

The start-up system **200** includes a casting onset detector **202** which has an input coupled to the line **47** as symbolized by the line **247** and has an output **204** which is coupled to means for energizing the billet drive system such as a drive motor energized **206**, and also to means for altering the drive speed for a pre-determined period such as a timed speed-up signal source **208**. The drive motor energizer **206** is preferably coupled to the billet drive motor **22**, as indicated by the line **210** to supply power thereto in response to the casting onset detector **202** output **204**.

The timed speed-up signal source operates to alter the control unit **40** so as to change the output or control signal on line **47** to the drive control **24** so as to increase the drive speed for a predetermined short period, and then to automatically restore it to the above described normal operation.

Referring now to FIG. **2**, the system **10** and especially the control circuit **40** and start-up system **200**, will now be explained in more detail. From an ac line voltage power source **51**, line **51A** and **51C** are connected to the ac power lines which may for example be **117** volts alternating current, such as commonly available in the United States, or may be some other alternating current source. The line **51A** is coupled through a safety fuse **52** and an on-off switch **53** to one side of a primary coil of a step-down transformer **54**. The line **51C** is coupled to the other side of the transformer **54**.

One side of the secondary coil of the transformer **54** is connected to a conduction line **31A** while the other side of the secondary coil of the transformer **54** is connected to a conduction line **31B**. Between the lines **31A** and **31B** is preferably connected an indicating lamp **55**. The lamp **55** as well as the primary actuating on-off switch **53** is preferably placed upon a control panel located remotely from the continuous casting mold **20**. The line **31B** is also connected through a resistor **56** to the line **31C**. The lines **31A** and **31C** form the signal input **31** to the primary coil **30P** of the induction level detector **30**.

Connected to the junction of the resistor **56** and line **31C** is a conductor **32C** and also connected to the junction of the resistor **56** and the conductor **31B** is a conductor **32A**. Between the lines **32A** and **32C** is connected the primary coil of a transformer **58**. The secondary coil of the transformer **58** is center tapped. This center tap is connected to one end of the primary of another transformer **59**. The other end of the primary coil of the transformer **59** is connected, through a capacitor **61**, to one end of the secondary coil of the transformer **58** and also through a resistance circuit **62** to the other end of the secondary of the transformer **58**. This resistance circuit **62** comprises a fixed resistance **62F** in parallel with a variable resistance **62V** which parallel connection is in series with a third resistance resistor **62S**.

The secondary coil on the transformer **59** has two intermediate tap points **63** and **64**. The tap **63** is a center tap. Between these two tap points **63** and **64** the bucking signal is derived.

This voltage is used as a bucking voltage for cancelling out or nulling the output from the secondary detector coil **30S**. To be able to adjust the amplitude of this bucking voltage, it is applied to the potentiometer **72** and fixed resistance **71**. The position of the tap on **72** determines the magnitude of bucking voltage introduced in series with the secondary detector coil **30S**.

The voltage taken from the tap of the potentiometer **72** is reduced in magnitude and shifted in phase from the primary signal impressed on the primary coil **30P** of the detector **30**. This reduced and phase shifted bucking voltage from the tap of the resistor **72** is connected to the line **39A** which is con-

nected to one end of the secondary coil 30S of the inductance detector 30. The other end of the coil 30S is connected to the line 39C and thereafter coupled to a band pass filter circuit 75 turned to the signal source frequency. This filter 75, forms part of the amplifier 41.

The band pass filter 75 is connected to an adjustable voltage source 130 via line 76 and the filter output is connected to line 77. The adjustable bias voltage input for the amplifier 80 through the filter 75 is formed by the voltage dividing resistor network 130 which includes a first resistor 131 connected to the B— line and one end of potentiometer 132 whose other end is connected through a resistor 133 to the B+ line. The arm on the potentiometer 132 is connected to the line 76. The line 77 is connected to the positive primary input of an operational amplifier 80. The operational amplifier 80, which may be a Motorola MC14336 type, is a well-known active circuit element which is here connected to serve as an ac low-frequency amplifier. The operational amplifier 80 has the line 77 from the band pass filter 75 connected to its primary positive input while its negative primary input is connected to a tapped resistor 78. One of the fixed terminals of the resistor 78 is connected to ground and the other is connected through a feedback resistor 79 to the output terminal of the operational amplifier 80.

In addition, the operational amplifier 80 has its conventionally numbered 6 and 8 terminals connected to source of positive voltage B+ over a line 81, has its numbered 9 and 10 terminals inter-coupled by a capacitor 82, has its output coupled through a capacitor 83 to its number 3 terminal, and has its number 4 terminal connected to a source of negative dc potential from the power supply via the line 85. The amplified ac signal from the operational amplifier 80 is capacitively-coupled, via a capacitor circuit 87, to a line 42A which is connected to one side of the primary coil of transformer 88. The other side of the primary of the transformer 88 is connected to ground.

The transformer 88, which forms part of the phase detector demodulator circuit 45, has a center tapped secondary coil, one end of which is connected through a single pole, double throw switch section 89, to a line 91. This line 91 is connected to a phase sensitive demodulator circuit generally designated 90. The opposite side of the circuit 90 is connected through a line 92 to another single pole, double throw switch section 93, to the other end of the secondary of the transformer 88. Across the other inputs of the bridge circuit 90 is connected the full secondary of the transformer 59 via the lines respectively designated 43A and 43C. Over these lines 43A and 43C are coupled the ac signal, indicated in FIG. 1, by line 43.

The bridge 90 is, more particularly, comprised of four solid state diodes 90A, 90B, 90C, 90D and four resistors 90W, 90X, 90Y, and 90Z. With a diode and a resistor connected in series forming each of four branches of the circuit 90. That is, the anode of the diode 90A is connected to the line 43A, while its cathode is connected through the resistor 90W to the line 91. Also the line 91 is connected through the resistor 90X to the line 91. Also the line 91 is connected through the resistor 90X to the anode of the diode 90B whose cathode is respectively connected to the line 43C. The diode 90C has its anode connected to the line 43C and its cathode connected through the resistor 90Y to the line 92. And the line 92 is connected through the resistor 90Z to the anode of the diode 90D whose cathode is in turn connected to the line 43A.

The variable level direct current output from the bridge circuit 90 is taken from the center tap of the secondary coil on the transformer 88 via line 94 which is connected to a filter or smoothing circuit 95. The circuit 95 includes a first resistor 96 connected to the line 94 and to one side of a capacitor 97 whose other side is grounded. The junction between the resistor 96 and capacitor 97 is, in turn, connected through resistor 98 to a second smoothing capacitor 99 whose other side is likewise grounded. The junction between the resistor 98 and capacitor 99 is connected through a resistor 101 to ground and also connected to the output line 47 between which and ground the drive control signal is developed.

The other side of the direct current output from the bridge circuit 90 is taken from the center tap 63 of the secondary coil on transformer 59. It is taken over conductor 93 to the tap of potentiometer 67. A dc voltage B'+ is applied to the network made up of potentiometer 71', potentiometer 67, and resistor 68. The settings of 71' and 67 determine the magnitude of dc voltage added in series with the output of the bridge circuit between center tap 63 and the ground reference plane.

The term ground plane is here used in the conventional electronic circuit sense and is not necessarily earth potential.

Also depicted in FIG. 3 is a read out and balancing meter 100 which serves a dual function of indicating the output voltage during normal operation and also aiding to achieve a balance null during set-up of the system 10. The meter 100 is a microammeter. One of its input terminals is connected through a current limiting resistor 103 to the line 47 and its other terminal connected through a single pole, double throw switch section 105 to ground. As such the meter 100 gives a direct reading of voltage output of the system. The meter 100 is preferably mounted on the control console for view by an operator.

In its balancing function, the meter 100 is connected through the other switch position of the switch section 105 to the center tap line 94 and is further connected through resistance network including the resistor 109 to the cathodes of two diodes 111 and 112. The anodes of the diodes 111 and 112 are respectedly connected to the second terminals of the switch sections 89 and 93. The switches 89, 93 and 105 are preferably ganged together so as to be thrown at the same time, as indicated by the line 113. When the switch sections 89 and 93 are thrown they connect the ends of the secondary coil of the transformer 88, through their respective diodes 111 and 112 and the resistor 109 to the microammeter 100. The other side of the meter 100 is connected to the center tap of the secondary of the transformer 88 via the line 94.

This circuit forms a full wage rectifier of the output of any ac voltage induced from the amplifier circuit 41. As at balance, we have specified that the bucking voltage connected from the taps 63—64 of the transformer 59 should cancel out the induced voltage of the secondary coil 30S of the inductive level detector. Thus, in a balanced condition no current would be produced by the full wave rectifiers and thus reading zero deflection on the meter 100 would be expected. The meter 100 may then be used to set up or balance the system 10 by adjusting various variable circuit elements to zero the meter 100, for the desired steel height in the mold 20. When so used the meter 100 is effectively functioning as an ac volt meter. As balance is approached, the sensitivity of the meter 100 may be increased by decreasing the effective resistance of the circuit as by adding the additional resistor 116 in parallel with the resistor 109 by depress-ing the sensitivity push-button switch 117.

The power supply source for B+, B— and B'+ is preferably the same as described in the above referred to patent application Ser. No. 3,421, although any equivalent power supply may be employed.

The start-up circuit 200 in accordance with the present invention includes a resistor 220 one end of which is connected via the conductor 247 to the output line 47. The other end of the resistor 220 is connected to one fixed end of a potentiometer 222 whose other fixed end is grounded. The movable tap of the potentiometer 222 is connected to the control electrode of a switching device 224, such as a Triac.

The controlled terminals of the Triac 224 are connected in series with a relay coil 230 and the secondary coil of an isolation transformer 240. The primary coil of the transformer 240 is connected across an alternating current source such as a 117v ac power source as is commonly available in the United States.

The relay coil 230 controls three switches 206, 232, and 233 as symbolized by the dashed line 204. The switch 206 is a normally closed switch and comprises the drive motor energizer. The switch 206 has its blade and normally-closed terminal connected to a pair of conductors 210 which are connected to the billet drive motor circuits.

The switch 232 has its blade connected to a positive voltage source B'+, its normally open terminal electrically unconnected and its normally closed terminal connected to a line 242. The normally open switch terminal of the third relay switch 233 is also connected to the line 242 while the normally closed terminal of that switch is unconnected.

The switch blade of relay switch 233 is connected through a resistor 244 to the base of a transistor 250. The base of the transistor 250 is also connected through the series connection of a variable resistor 246 and capacitor 248 to the line 242. The transistor 250 is an NPN transistor and has its emitter grounded and its collector connected to the line 69.

OPERATION OF FIGURE 2

As mentioned above, in overall operation the circuit of FIG. 2 produces during normal operation a direct current voltage on line 47 which dc voltage varies from a nominal level in magnitude and direction corresponding to the magnitude and direction of change in the height of molten steel within the mold 20. During start-up, operating it detects the onset of casting, energizes the motor drive system and runs that system at a higher speed for an initial period before automatically achieving the normal operation.

The input signal source 41 couples an ac signal of line frequency to the lines 31A and 31C and thus impresses that signal upon the primary coil 30P. A signal proportionate to this primary coil 30 P signal is developed across resistor 56 and thus coupled to the transformer 58 and from this to the transformer 59. Adjustment of the variable resistor 62V in the resistance circuit 62 allows for shifting the phase of the output of the transformer 59. Thus, the transformer 59 provides, between its tap points 63 and 64, an alternating current signal of reduced magnitude and shifted-phase from that of the input signal developed in the primary 30P.

Whenever a signal is developed in the secondary 30S it has to "buck" the signal picked off at point 72. The harmonics of the fundamental frequency injected into the primary, such as may be generated in the secondary, are eliminated by the band pass filter 75 so that only fundamental frequency signals are presented to the operational amplifier 80. With a deviation from the desired molten steel level, a small ac signal of the fundamental frequency will be present on line 77. This ac signal is amplified by the operational amplifier 80 coupled through the dc blocking capacitance 87 and coupled through the transformer 88.

The center tap 94 of the transformer 88, in relationship to ground, develops a nominal signal in the absence of any ac signals by the setting of the potentiometer 67 which governs the dc potential at the center tap 63 of transformer 59. This may, for example, be set for a nominal value of 2 volts.

The demodulator 90 functions to develop a net negative or positive voltage at the line 94, relative to center tap 63, from the ac signal amplified by the amplifier 80 and coupled thereto by the transformer 88 and lines 91 and 92 whenever the coupling between the coils 30P and 30S is more or less than that existing at the desired molten steel height.

The output voltage at line 94 with respect to ground is thus the dc value at center tap 63 established by the setting of potentiometer 67, plus the positive or negative output from the demodulator 90. The dc level established by the setting of 67 determines the set point or operating level, while the output from the demodulator provides a corrective signal to adjust the drive control unit 24 and maintain a constant steel level in the mold.

It should be pointed out that the system is relatively insensitive to changes in input signal level from the power source 51 or to changes in primary coil or circuit resistance 30, 31. This is because the bucking voltage from transformer 59 is derived from transformer 58 which receives its excitation from the voltage drop across resistor 56. Thus, if the line voltage 51 should drop or the resistance of coil 30P should increase, the current in 30P decreases and the induced secondary voltage in 30S also decreases. However, a reduction in current in 30P also reduces the voltage across resistor 56 and thereby reduces the bucking voltage developed from transformer 59. Thus, there is no net change in the signal to filter 75 and operational amplifier 80, and the level of steel in the mold is unaffected by change in line voltage 51 or changes of coil resistance 30P.

The start-up circuit 200 takes no part in the operation of the control circuit 40 during the above described normal running operation. When energized prior to the starting-up of the casting process the adjustment of the potentiometer 222 is such that the Triac 224 is conducting for an extremely low steel level in the mold 20. This conduction of the Triac 224 energizes the relay coil 230 which in turn holds the switch 206 open to maintain the billet drive motors de-energized. It also maintains the switch 232 open and the switch 233 closed.

The maintaining of the switch 233 closed for a period assures that the capacitor 248 is fully discharged. As the base of the transistor 250 is effectively unconnected, the transistor 250 is biased "off" or non-conductive between its collector and emitter. Thus, when the mold 20 is empty prior to start of casting, the relay is energized and the drive system is de-energized. At the onset of casting, the steel rises in the mold 20 and the control signal amplitude to the Triac 224 decreases. At the operating threshold, the triac 224 stops conducting. This releases the relay and starts the casting machine drive system. Another set of relay contacts, switch 232, applies a "turn on" signal to the transistor. Transistor conduction reduces the offset potential which is added to the basic output signal. The effect is to initially speed up the drive system. This compensates for the thermal time delay associated with the mold parts and allows the mold to approach thermal equilibrium without danger of the steel overflowing the mold. As the capacitor 248 approaches full charge, the transistor approaches cut-off, thereby applying full control voltage to the output signal. Thereafter normal operation continues. The switch 233 assures that the capacitor is fully discharged at the beginning of each start cycle.

This operation may be illustrated by reference to FIG. 3, wherein a curve A represents the relationship between the control system output signal, line 47, on the x-axis and the steel level in the mold 20 on the y-axis for a particular system 10. In this system 10 the nominal or desired level of steel during normal operation is represented by the dashed line 260 and an "off-set" voltage level corresponding to that level is represented by the vertical dashed line 261. (This may be zero or any other voltage, but in the particular system disclosed it is +2 volts dc.)

Prior to casting start-up, the level of steel lies below a level 262 which corresponds to the voltage level at which the Triac 224 operates in the circuit of FIG. 2. When moltant steel is poured into the mold 20 the level rises to above the line 262 and a change in output voltage de-energizes the relay coil 230. This alters the output voltage to approximately zero voltage for a period determined by the time constant of the resistance-capacitance circuit formed by the resistor 246 and capacitor 248. As the charge on the capacitor rises, the transistor 250 approaches cut-off to gradually restore the operation to normal.

FIGURE 4 EMBODIMENT

In FIG. 4 a modification of the circuit 200 is depicted in which the control terminal of the triac 224 is connected directly to line 47 and the resistor circuit 220' and 222' is connected between one of its controlled terminals and ground. Also the blade of the switch 232 is connected to the collector of the transistor 250 and to the line 69. This circuit has the advantage of eliminating the resistor 246, but loses the versatility that the resistor, provided. Its operation is the same as the previous circuit. The circuit of FIG. 4 was constructed and tested in the environment of a continuous steel casting mode and provided satisfactory performance.

Various of the features of the invention have been particularly shown and described, however, it should be obvious to one skilled in the art that various modifications may be made therein without departing from the scope of the invention.

I claim:

1. In a continuous casting system of the type in which a control signal is developed which is predominately proportional to the height of molten metal in a continuous casting mold which signal is used in normal operation to control the speed of withdrawal of the continuous casting from the mold by a drive system, the improvement in a start-up system comprising:

means for detecting the onset of casting;

second means coupled to said detecting means for governing the speed of the drive system in a definite manner for a definite start-up period after the detected onset so as to control the drive system independently of the detected height for that period and for automatically restoring the control signal to its normal operating condition at the end of that predetermined period;

means coupled to said detecting means for energizing the drive system and in response to the detection of the onset of casting;

said second means governing the drive system speed by altering the control signal; and

said casting onset detecting means is coupled to the level control signal for operation of the energizing means and said second means when the control signal passes a threshold value;

said detecting means including:

a switching device coupled to the control signal for control thereby, and

a relay coil connected to said switching device for energization and de-energization in response thereto;

said drive energizing means is a first relay switch controlled by said relay coil; and

said second means including:

at least, one additional relay switch controlled by said relay coil,

a second switching device coupled alternately change the control signal and to not effect the control signal, and

a timing circuit coupled to both said second switching device and said at least one additional relay switch, for controlling said second switching device in response to the relay coil so as to change the control signal for the predetermined period and to thereafter not effect that signal;

whereby the continuous casting system may automatically reach normal operating conditions from the onset of casting without the necessity of human observation and control and without molten metal spill-over or break-out caused by transient start-up conditions.

2. The improvement in a start-up system for a continuous casting system as defined in claim 1 wherein:

said detecting means switching device is a solid-state bi-directional switch (224) which has its control electrode connected to receive the signal and is so biased so as to be conducting for signals indicating that the height of molten metal in the mold is below a certain level and to be non-conducting for signals indicating that the height is above that level;

said first switch (206) is a normally closed switch;

said additional relay switch (232) is a normally closed switch connected in series with a source of potential (B'+) and said timing circuit (248, 246) so as to connect said potential source and said timing circuit when closed;

said timing circuit includes a resistance (246) and a capacitance (248) in circuit connection together and connected to said second switching device;

said second switching device (250) is a transistor having its emitter-collector circuit connected between a plane of potential and the control signal source, and its base connected to said timing circuit; and

said second means further includes a third relay switch (233) that is normally open, is controlled by said relay coil, and is connected across said capacitance (248);

so that for low levels of molten metal in the mold said solid-state bi-directional switch is maintained conductive so as to maintain said first switch open, said additional switch open and said third switch closed to insure that said capacitance is effectively uncharged, and for reversing the conditions of said switches when the molten metal height exceeds said certain height thereby causing the energization of the drive system, the rendering of the second transistor conductive to alter the control signal for a period depending upon the charging time of said resistance and capacitance timing circuit and for thereafter rendering said second transistor non-conductive.

3. A mold level control system for controlling the level of molten metal in the mold core of a continuous casting mold of the type that has a core which includes a highly conductive layer and which mold receives molten metal from a source and from which a continuous billet of at least partly hardened metal is extracted by a variable speed drive system, a mold level detector, which detector is positioned adjacent to the mold core; and

said mold level detector comprises a first coil and a second coil;

means coupled to said mold level detector and to the billet drive system for controlling the speed of the billet drive system in response to said detector so as to vary the speed thereof to maintain, during normal operation, the level of the molten metal within a desired predetermined range;

said controlling means including:

a signal source coupled to said one coil for exciting it with an ac input signal,

means coupled to said second coil for deriving an output signal therefrom which is related to the input signal and to the level of molten steel in the mold;

a source of a second signal related to the input signal but phase shifted therefrom, and

means coupled to said output signal deriving means and said second signal source for deriving a dc mold level control signal whose amplitude varies in proportion with changes in the level of molten steel in the mold core from a predetermined level therein;

means coupled to said billet drive speed control means for, during start-up, operating the billet drive system at a programed rate of speed for a definite time period after the onset of casting and for restoring the system to normal operation after that time period; said start-up means including:

a casting onset detector coupled to receive the control signal;

switching means coupled to the casting onset detector and the billet drive system for energizing and de-energizing that drive system when the control signal is above or below a predetermined threshold amplitude;

a timed speed-up signal source coupled to said casting onset detector and said control signal deriving means for coupling a speed-up signal thereto for altering the control signal to cause the billet drive system to operate at the programed rate of speed, said speed-up signal source including timing means for discontinuing the speed-up signal at the end of a predetermined time period from the detection of casting onset.

4. The mold level control system for controlling the level of molten metal in a mold core, as defined in claim 3, wherein:

said casting onset detector includes:

a switching device coupled to the control signal for control thereby, and

a relay coil connected to said switching device for energization and de-energization in response thereto;

said drive energizing means is a first relay switch controlled by said relay coil; and

said second means includes:

at least, one additional relay switch controlled by said relay coil,

a second switching device coupled alternately change the control signal and to not effect the control signal, and

a timing circuit coupled to both said second switching device and said at least one additional relay switch, for controlling said second switching device in response to the relay coil so as to change the control signal for the predetermined period and to thereafter not effect that signal.

5. The mold level control system for controlling the level of molten metal in a mold core, as defined in claim **4**, wherein:

said detecting means switching device is a Triac bi-directional switch (**224**) which has its control electrod connected to receive the signal and is so biased so as to be conducting for signals indicating that the height of molten metal in the mold is below a certain level and to be non-conducting for signals indicating that the height is above that level;

said first switch (**206**) is a normally closed switch;

said additional relay switch (**232**) is a normally closed switch connected in series with a source of potential (B'+) and said timing circuit (**248, 246**) so as to connect said potential source and said timing circuit when closed;

said timing circuit includes a resistance (**246**) and a capacitance (**248**) in circuit connection together and connected to said second switching device;

said second switching device (**250**) is a transistor having its emitter-collector circuit connected between a plane of potential and the control signal source, and its base connected to said timing circuit; and

said second means further includes a third relay switch (**233**) that is normally open, is controlled by said relay coil, and is connected across said capacitance (**248**);

so that for low levels of molten metal in the mold said triac is maintained conductive so as to maintain said first switch open, said additional switch open and said third switch closed to insure that said capacitance is effectively uncharged, and for reversing the conditions of said switches when the molten metal height exceeds said certain height thereby causing the energization of the drive system, the rendering of the second transistor conductive to alter the control signal for a period depending upon the charging time of said resistance and capacitance timing circuit and for thereafter rendering said second transistor non-conductive.

6. A continuous steel casting system comprising:

a source (**12**) of molten steel,

a mold unit (**20**) having a generally vertical core into which said source pours molten steel at an approximately constant and continuous rate, and about which a coolant is circulated and from which a continuous steel billet is produced;

an inductance level detector (**30**) positioned in said mold unit adjacent to but outside of said core to detect the level of molten steel in the core;

a billet drive system (**16**) that is responsive to a drive control signal to vary the rate of removal of the billet from the mold core;

a source (**41**) of excitation signals coupled to said inductance detector,

means (**40** and **21**) coupled to said inductance level detector for extracting therefrom a signal indicative of the level of molten steel therein and for determining there-from a variable drive control signal therefrom, and for coupling that control signal to said billet drive system;

start-up means (**200**) responsive to the control signal indicating a low level below predetermined level of molten steel in said mold unit for de-energizing said drive system and, in response to a control signal indicative of the rise of molten steel above that predetermined level for re-energizing said drive system and for altering said control signal, for a short predetermined time period, so as to operate said drive system at a high rate of speed of billet withdrawal for that short predetermined time period, and for then automatically ceasing that signal alteration.

7. In a continuous casting system of the type in which a control signal is developed which is predominately proportional to the height of molten metal in a continuous casting mold which signal is used in normal operation to control the speed of withdrawal of the continuous casting from the mold by a drive system, the improvement in a start-up system comprising:

first means for detecting the onset of casting coupled to receive and respond to the height proportional control signal;

second means coupled to said first means for governing the speed of the drive system in a definite manner for a definite start-up period after the detected onset so as to control the drive system independently of the detected height for that period and for automatically restoring the control signal to its normal operating condition at the end of that definite start-up period;

whereby the continuous casting system may automatically reach normal operating conditions from the onset of casting without the necessity of human observation and control and without molten metal spill-over or break-out caused by transient start-up conditions.

8. The improvement in a start-up system for a continuous casting system as defined in claim **7**, wherein said start-up system further includes:

means coupled to said first means for energizing the drive system and in response to the detection of the onset of casting; and wherein

said second means governs the drive system speed by altering the control signal impressed thereto.

9. The improvement in a start-up system for a continuous casting system as defined in claim **8**, wherein:

said first means is coupled to the level control signal for operation of the energizing means and said second means when the control signal passes a threshold value.

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