United States Patent

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[33] **Switzerland**
[31] **18,044/65**

[54] **METHOD OF CONTROLLING CONTINUOUS CASTING**
8 Claims, 20 Drawing Figs.

[52] **U.S. Cl.** **164/4,** 164/155
[51] **Int. Cl.** **B22d 11/10,** B22d 1/02, B22d 17/32
[50] **Field of Search** 164/4, 82, 154, 155, 274, 281, 152, 153

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Primary Examiner—J. Spencer Overholser
Assistant Examiner—R. Spencer Annear
Attorney—Sandoe, Neill, Schottler & Wikstrom

ABSTRACT: In a continuous casting plant sensing elements responsive to the metal supply to the mold, to the level of metal in the mold or in the partly solidified casting, and/or to a breakthrough of liquid metal from the casting generate signals that are automatically analyzed and applied to control the supply of metal to the mold, the rate of withdrawal of the casting from the mold and/or the cutting of the casting.

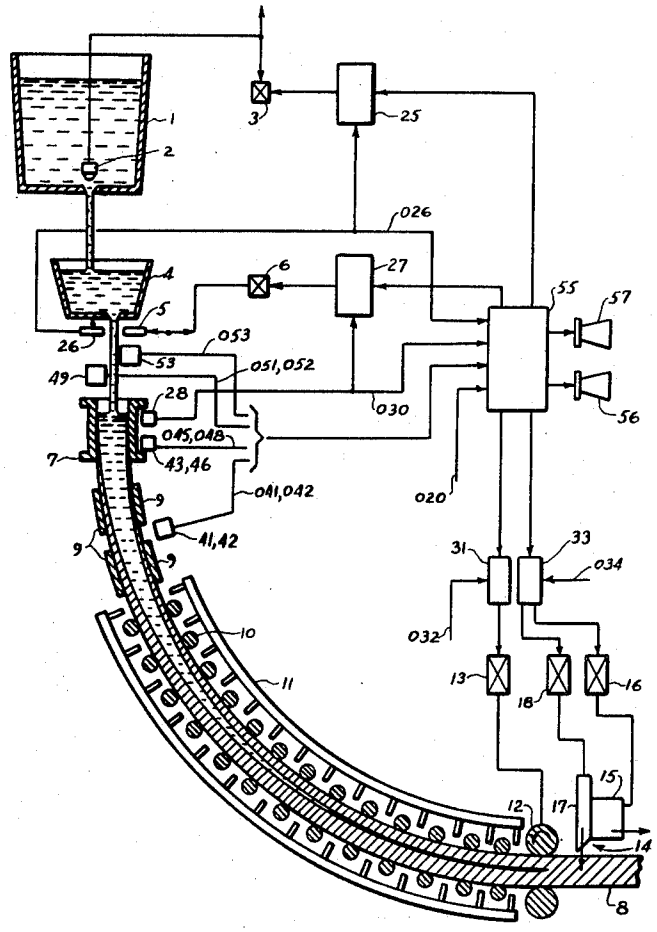
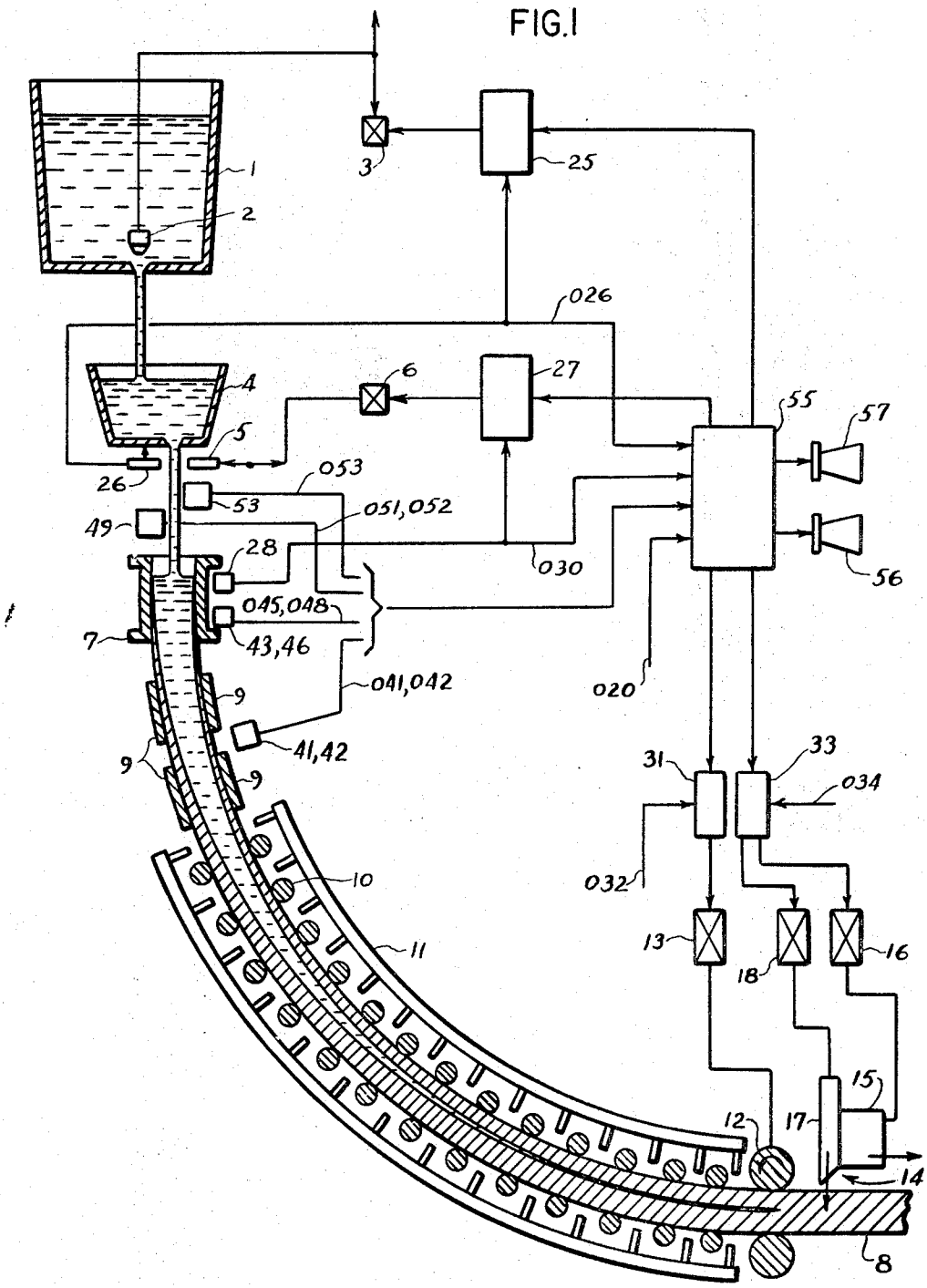


FIG.1



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FIG.2

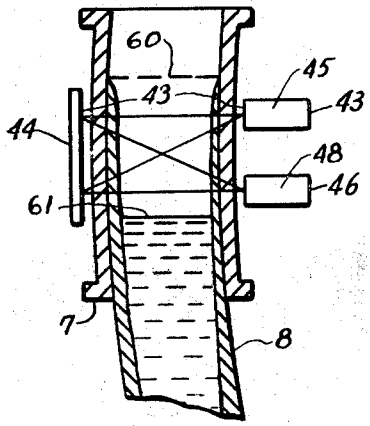


FIG.3

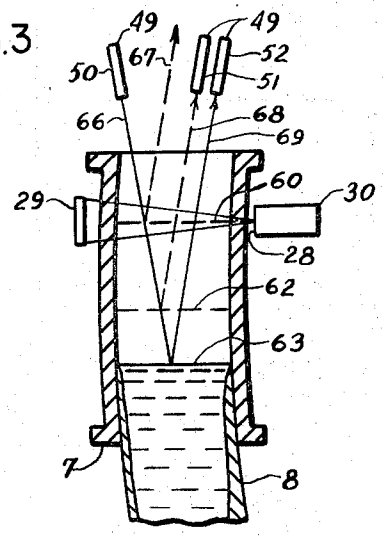


FIG.4

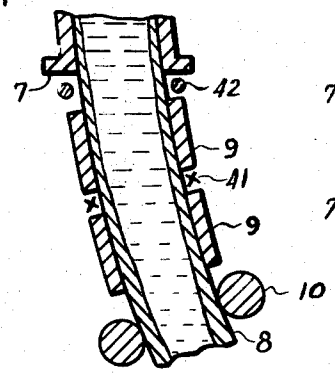


FIG.5

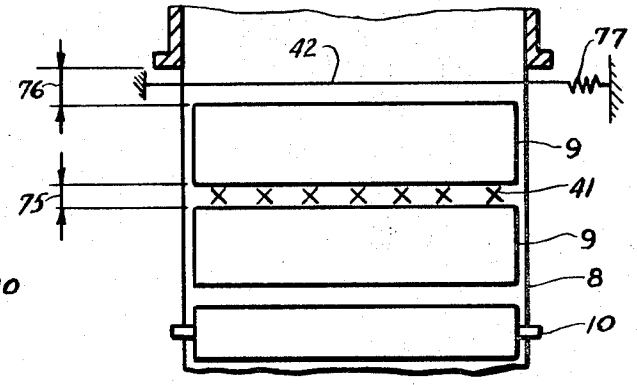


FIG.6

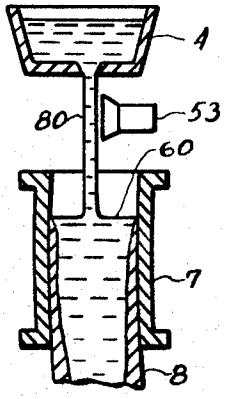
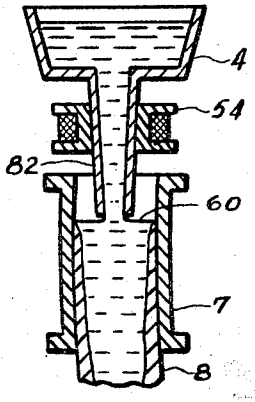


FIG.7



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FIG.8

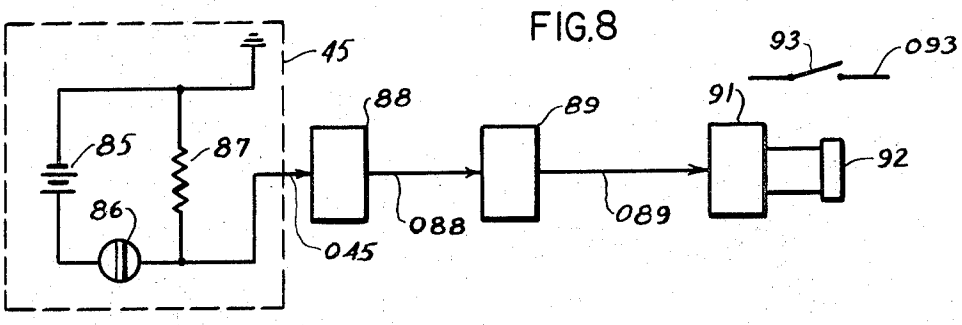


FIG.9

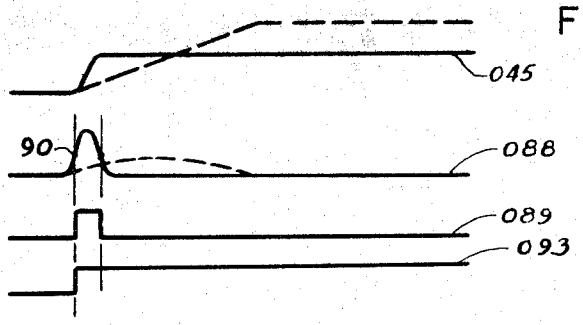
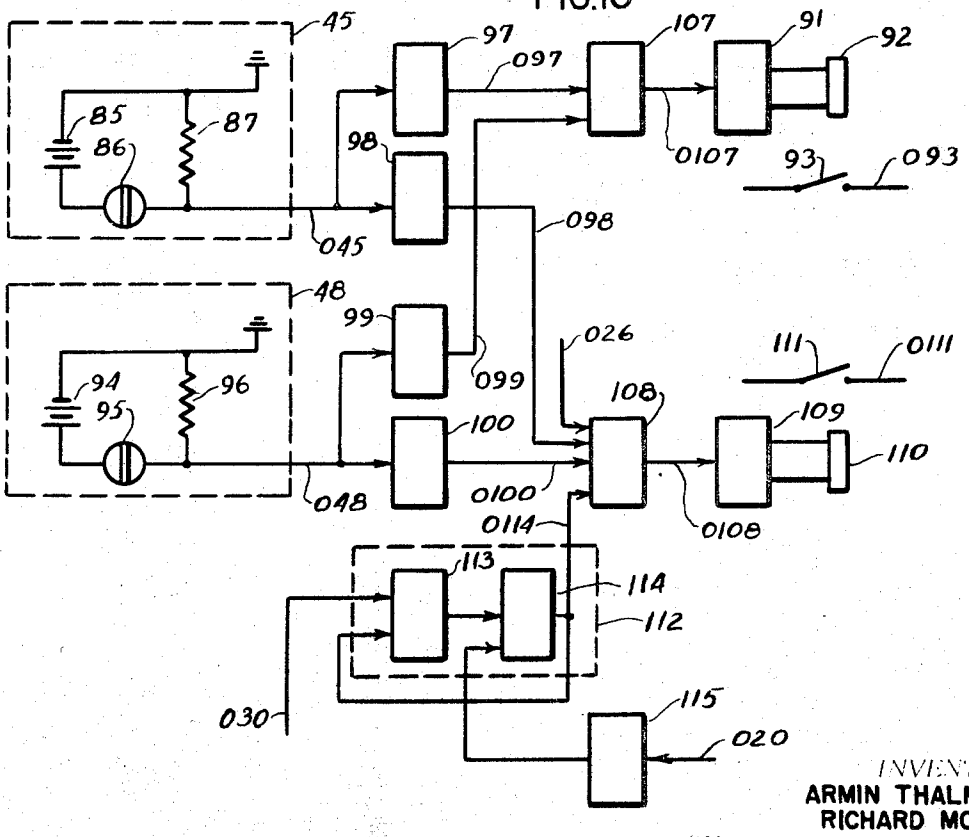


FIG.10



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FIG.11

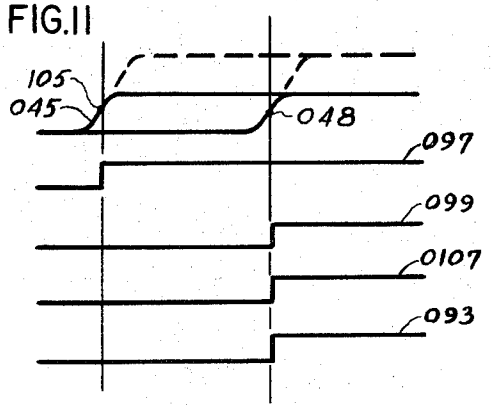


FIG.12

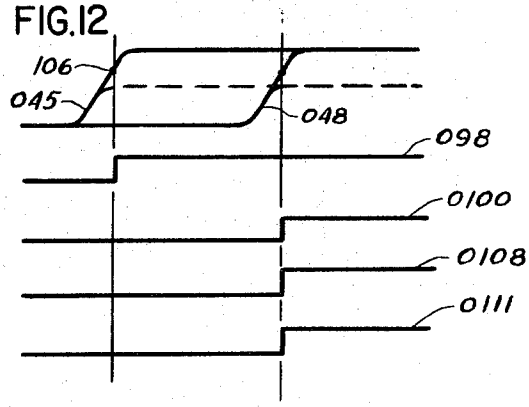


FIG.13

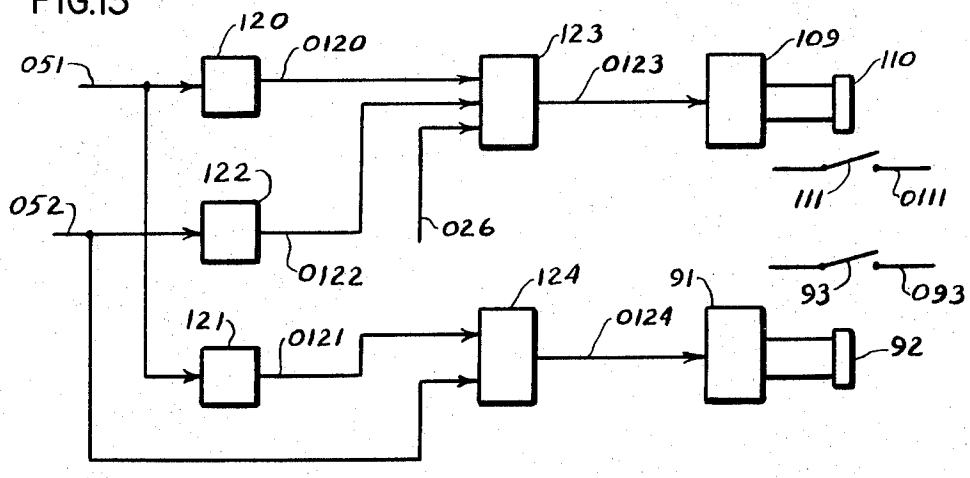


FIG.14

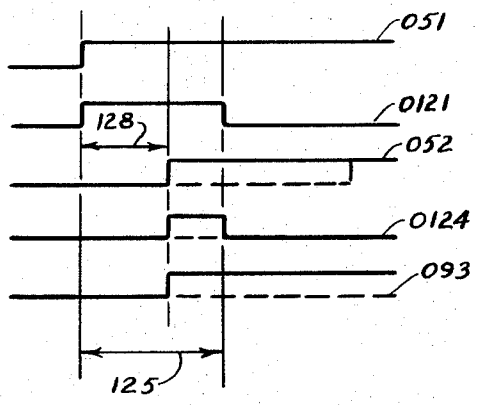
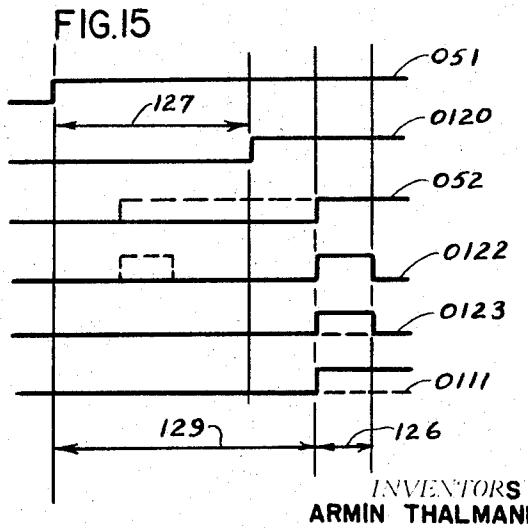


FIG.15



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FIG.16

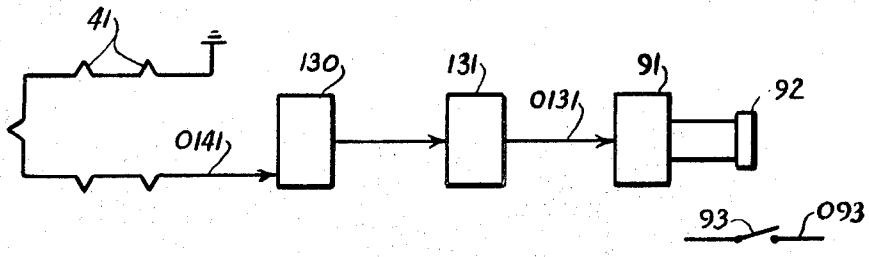


FIG.17

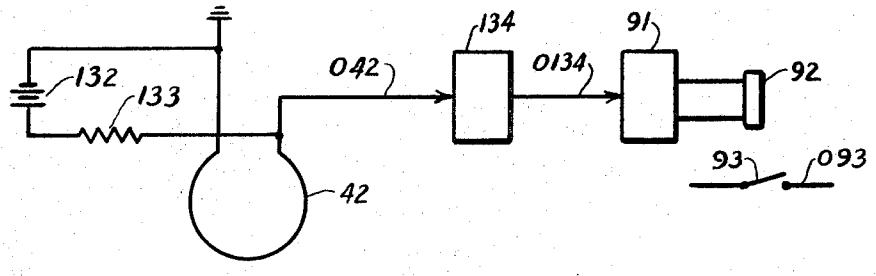


FIG.18

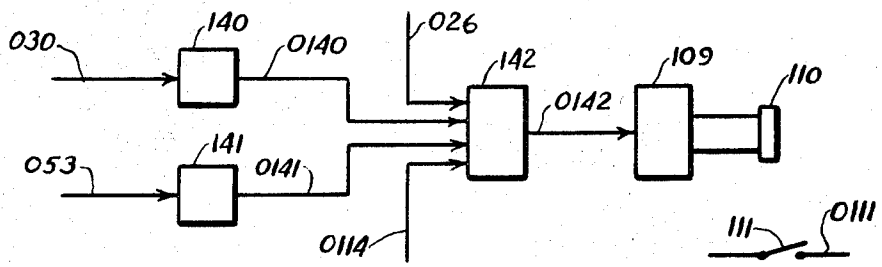
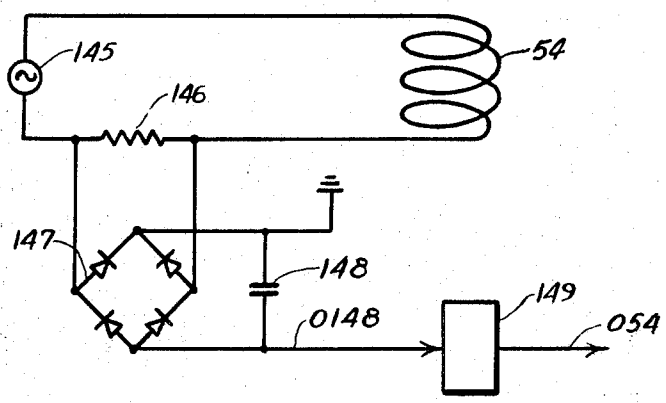


FIG.19

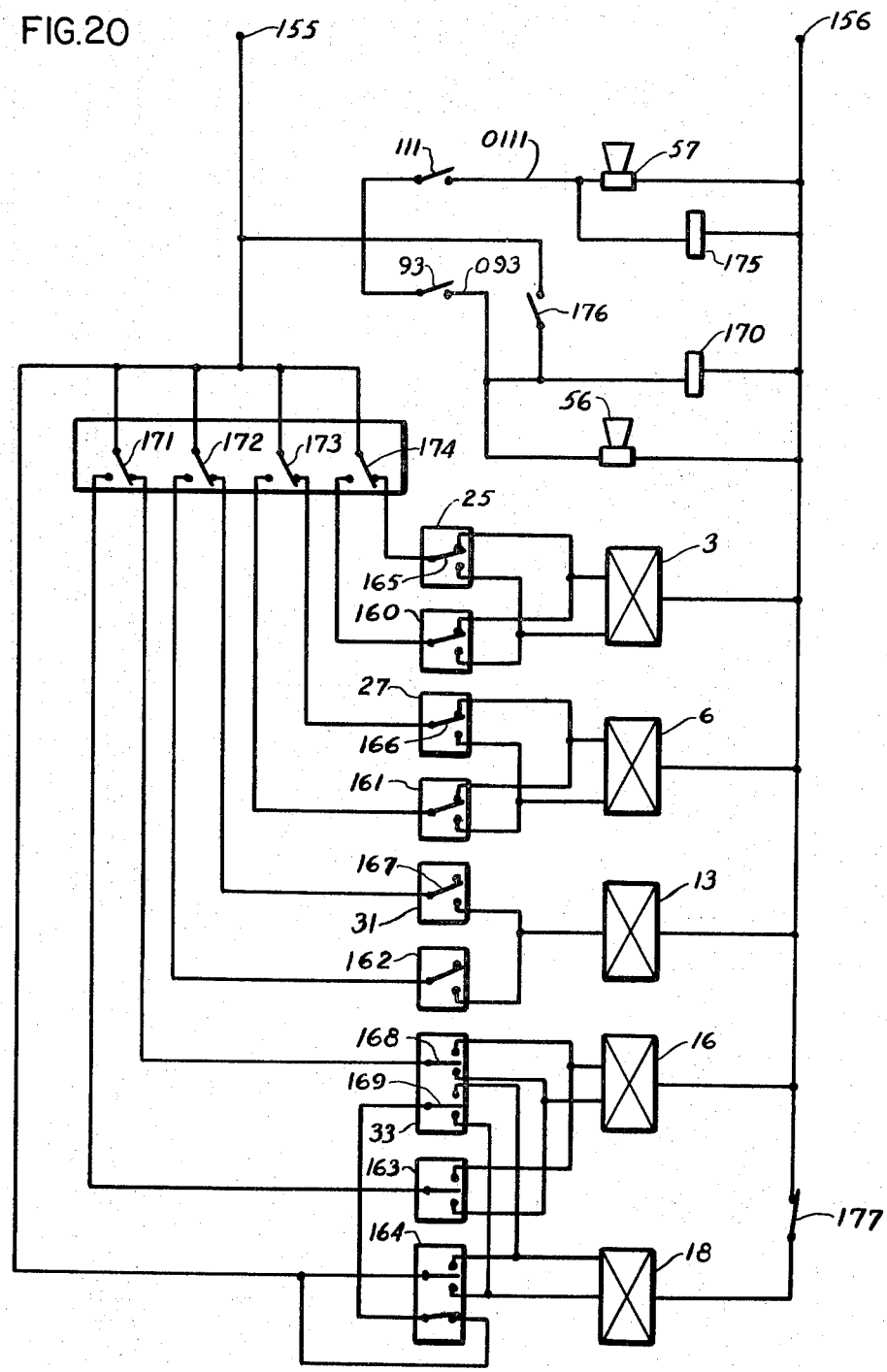


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FIG.20



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METHOD OF CONTROLLING CONTINUOUS CASTING

This is a division of application Ser. No. 606,147 filed Dec. 30,1966, now abandoned.

A signal indicating a fall in the level of molten metal in a continuously cast strand or in the molten metal in the continuous casting mold is fed to a switching network which analyzes the type of fault and automatically initiates control signal for plant correcting control.

The present invention relates to a method of controlling a continuous casting plant when a fault in operation arises which results in a fall in the level of the metal pool in the mold.

Continuous casting plant are usually operated by manual control means. Automatic controls that have been proposed include arrangements for weighing the metal for the purpose of checking the level of the metal in pouring vessels, as well as arrangements for monitoring the level of the metal pool in the mold. The first of these devices is used for controlling the rate of metal supply and the second for controlling the rate of withdrawal of the casting from the mold.

Some of the work of manual control is undertaken by electrical elements. In order further to reduce the work involved in an manual control in favour of automatic control, means must be provided for monitoring and indicating operational faults which may occur whilst casting proceeds.

The most troublesome fault during continuous casting is an eruption or breakthrough of liquid metal which may be due to unpredictable causes of a metallurgical and mechanical kind.

Moreover, during continuous casting troubles may arise in connection with the supply of liquid metal to the casting mold. One type of fault, caused for instance by a gating valve jamming in open position, may lead to an excessive supply of liquid metal into the mold. It has already been proposed to provide monitoring means which generate a signal when the level of the liquid pool in the mold rises beyond a fixed maximum level and to use the signal for activating an alarm.

In a different group of faults, due for instance to a partial blockage of the ingate by a fragment off the plug, the supply of metal to the mold is insufficient.

A known arrangement for monitoring the level of the liquid pool in the mold seeks to indicate such a deficiency by generating a signal when the level of the pool falls below a minimum level, the signal being similarly used to activate an alarm or to reduce the rate of withdrawal.

However, it has not yet been recognised that a fall in the level of the liquid pool may also be due to other causes which call for immediate remedial action. A fall in the level of the liquid metal also occurs when there is a breakthrough of metal through the crust of the partly solidified casting. Moreover, when casting begins and when casting ends liquid metal is absent at the minimum level. Consequently the signal derived from such a minimum level monitoring device has no unique meaning, in other words it does not indicate the nature of the fault or the operating conditions causing the indicated condition.

It is therefore the object of the present invention to provide control means for a continuous casting plant which respond to a breakthrough of metal as well as to a deficiency in the rate of metal supply in such manner that the appearance of a corresponding signal will permit immediate corrective controlling action to be initiated.

According to the invention this is achieved in that at least one element is provided which generates a signal characteristic of the type of fault that has occurred and that by reference to said signal the plant is controlled in the manner required for dealing with the particular fault.

The system for performing this method is characterised by electrical switching elements which evaluate the signal of the element indicating the fault, and which are associated with storage elements.

For unambiguously indicating the occurrence of breakthrough of metal the signal reporting the fault may be derived from an element which responds to a fall in the level of the liquid metal in the partly solidified casting. Alternatively this signal may also be drived from an element which responds to the liquid metal issuing from the partly solidified casting.

For unambiguously indicating a deficiency in metal supply to the mold the fault signal may be derived from an element which responds to a fall in the level of the metal pool in the mold. Alternatively this signal may be derived from an element which monitors the size of the teeming metal jet.

For generating a signal indicating a fall in the level of the metal in the partly solidified casting or in the level of metal pool in the mold three possibilities are available:

a. A level indicator may be arranged to supply an analogous signal. The rate at which the level of the metal falls may then decide which kind of fault signal must be generated.

b. A level monitoring means may be arranged to supply signals at two levels. The signal magnitudes at these levels may then be used to decide the nature of the fault generating the signal.

c. Digital signals may be generated at two levels. The nature of the fault signal is then determined by the interval in time between the signals at the two levels in relation to a predetermined time interval.

The signals generated by the proposed elements may also be subject to the effects of other signals, as will be later described, for bridging the operating states which arise at the beginning and end of the casting process and for avoiding unwanted fault signals during these phases.

Other features of the invention will be understood from the following description of embodiments of the invention with reference to the drawings in which:

FIG. **1** is an elevation cross sectioned view of a continuous casting plant, with sensing and control circuitry in schematic form;

FIG. **2** is a cross section of a continuous casting mold with monitoring means providing two level indications, and comprising a radiation source and radiation detectors;

FIG. **3** is a cross section of a continuous casting mold with monitoring means providing two level indications, and comprising a transmitting and detecting system for electromagnetic waves;

FIG. **4** is a cross sectioned view of a cast strand having two elements responsive to flowing metal from a breakthrough;

FIG. **5** is a side elevation of the system according to FIG. **4**;

FIG. **6** is a cross section view of a continuous casting plant with a pyrometer responsive to the size of the teeming jet;

FIG. **7** is a cross sectioned view of a continuous casting plant with a magnetizing coil responsive to the size of the teeming jet;

FIG. **8** is a schematic diagram of the electrical system for evaluating the signal from one level according to FIG. **2**;

FIG. **9** is a plot of the wave forms at different points of the circuit of FIG. **8** illustrating the form of signal obtained when a breakthrough occurs;

FIG. **10** is a schematic diagram of the electrical system for evaluating the signals derived from two levels according to FIG. **2**;

FIG. **11** is a plot of wave forms at different points in the circuit of FIG. **10** illustrating the form of the signals obtained in the event of a breakthrough;

FIG. **12** is a plot of wave forms at different points in the circuit of FIG. **10** illustrating the form of the signals obtained in the event of a deficient metal supply;

FIG. **13** is a schematic diagram of an electrical system for evaluating signals received from elements according to FIG. **3**;

FIG. **14** is a plot of wave forms at different points of the circuit of FIG. **13** illustrating the form of the signals in the event of a breakthrough;

FIG. **15** is a plot of wave forms at different points of circuit of FIG. **13** illustrating the form of the signals in the event of a deficient metal supply;

FIG. **16** is a schematic diagram of an electrical system for evaluating the signal from temperature-responsive elements according to FIGS. **4** and **5**;

FIG. 17 is a schematic diagram of an electrical system for evaluating signals from fusible members according to FIGS. 4 and 5;

FIG. 18 is a schematic diagram of an electrical system for evaluating signals obtained from a pyrometer according to FIG. 6;

FIG. 19 is a schematic diagram of an electrical system for evaluating signals obtained from a magnetizing coil according to FIG. 7; and

FIG. 20 is a schematic diagram of an electrical circuit layout for controlling the drive means and the servo elements which regulate the supply of steel.

In FIG. 1 there is shown a continuous casting plan plant with a curved mold and a curved casting guide, comprising a pouring ladle 1 with a plug 2 controlled by servo means 3. The metal flows from the ladle into a further intermediate pouring vessel or tundish 4. The gate of the tundish 4 is controlled by a slide valve 5 operable by servo means 6. From the tundish 4 the metal flows into a curved water-cooled continuous casting mold 7 in which a continuous casting 8 with a liquid core forms. This casting 8 is withdrawn from the mold 7 by withdrawing rollers 12 and is assisted by rollers 10 through the casting guide in which the casting is further cooled by sprayers 11. After having passed between the withdrawing rollers 12 which are driven by drive means 13 the casting 8 is cut into lengths by a cutting device. The cutting device 14 is associated with synchronising gear 15 which moves the cutting device at the same speed as a casting during the cutting operation. The synchronising gear 15 is driven by drive means 16. The cutting device 14 is also equipped with traversing gear 17 which guides and moves the cutter burner across the axis of the casting.

The servo means 3, for example in the form of a motor-driven lifting gear for raising and lowering the plug 2, is controlled by a controller 25. The tundish 4 is preferably fitted with weighing equipment in the form of load gauges 26. The load gauges 26 permit the level of the metal surface in the tundish 4 to be inferred from the weight of the metal. Preferably the load gauges are associated with means which respond to three levels of the metal surface, namely a maximum level, a minimum level and an absolute minimum level. Response to these levels affects the controller 25 and results in actuation of the plug 2. At maximum level the plug 2 is closed, at minimum level it is opened. The effect of the absolute minimum level will be later described.

The servo means 6, which may be a hydraulic actuator for operating the slide valve 5 is controlled by a controller 27. The top of the mold 7 is fitted with level monitoring means 28, preferably comprising a radioactive source in the form of a rod and radiation detectors. The level monitoring means 28 respond to two levels of the metal pool in the mold 7, namely a maximum level and a minimum level. These two level indications are applied as signal 030 to an input of the controller 27 and cause the slide valve 5 to be operated. At maximum level the valve is closed and at minimum level it is opened. However, level monitoring means comprising rod sources are also suitable for continuously checking the volume of metal.

The drive means 13 for the withdrawing rollers 12 are controlled by a controller 31. This controller 31 which determines the normal rate of withdrawal of the casting can be influenced by information 032 which need not here be specified in detail, such as information relating to the thickness of the crust, the temperature of the casting and so forth.

At 33 is a further controller which controls the two drive means 16 and 18 associated with the cutter device 14. This controller 33 which determines the normal operation of the cutter operates by reference to information 034 which need likewise not here be described in detail, such as the length of the portions to be cut off, the temperature of the casting and so forth.

For the generation of signals indicating the presence of faults FIG. 1 illustrates three arrangements feasible for such applications:

d. For indicating a breakthrough of metal temperature responsive elements 41 such as thermoelements may be provided between the two cooling members marked 9. Should any metal break through the crust of the partly solidified casting these elements generate a signal 041.

In additionally or alternatively fusible members 42, such as metal bands tensioned by springs may be provided at this point. If liquid metal breaks through, these likewise generate a signal 042.

e. Near the bottom end of the mold 7 are two level indicators 43 and 46 comprising a radioactive source in rod form and a radiation detector associated with each level. When the level of the metal in the partly solidified casting or the level of the metal pool falls below the levels of these indicators 43 and 46 signals 045 and 048 are generated.

Further level indicators in the form of a transmitting and detecting system 49 for electromagnetic waves are provided above the mold 7. If the level of the liquid metal in the mold falls to critical levels at which the rays are reflected at the metal surface so that they fall into one of the detectors, the latter will generate a signal 051 or 052 respectively.

f. A deficiency of metal supplied to the mold 7 may be detected by monitoring the size of the teeming metal jet. A deficient supply may be due to one of several reasons. For instance, the gate may freeze, the flow of metal through the gate may be obstructed by a fragment of the plug, a slide valve may freeze and so forth. For monitoring the size of the teeming jet a pyrometer 53 is provided above the mold 7, which responds to the light radiated by the jet. This pyrometer generates a signal 053.

Alternatively, as indicated in FIGS. 7 and 19, at the same point above the mold a magnetizing coil 54 may be provided if the gate is provided with a spout extending to the surface of the pool. A signal 054 can then be generated which reflects the magnitude of the eddy current loss in the liquid metal.

The manner in which use can be made of these three possibilities in principle of generating signals will be later described in greater detail with reference to FIG. 2 to 7. According to the arrangements provided, the signals 041, 042, 045, 048, 051, 052, 053, and 054 (FIG. 19) are fed to a safety controller 55.

Other information may also be fed to this controller at the same time. Information of such a kind may comprise:

g. A signal 026 indicating the absolute minimum level of metal in the feed head;

h. A signal 020 indicating that casting is in progress in the plant; and

i. A signal 030 derived from the minimum level indicator of the pool monitoring means.

The signals enumerated in points g, h and i will be referred to later.

The controllers 25, 27, 31 and 33 operate under the control of the safety controller 55 which in the event of a fault also activates an alarm 56 when there is a breakthrough of metal or an alarm 57 where there is a deficiency of metal supply.

FIG. 2 illustrates the provision, at the lower end of the mold 7, of two level indicators 43 and 46, comprising a rod-shaped source 44 and two radiation detectors 45 and 48. Each detector 45, 48 may consist of a cadmium sulphide crystal which varies its electrical resistance according to the radiation dose which it receives. In normal operation the level of the pool of metal in the partly solidified casting 8 should be as indicated by the dashed line 60. Since the radiation is absorbed by the metal at the detector levels 43 and 46 the resistances of the detectors will be high. However, if, as a consequence of a breakout of liquid metal, the level of the metal in the partly solidified casting 8 falls to the level 61 below the two detector levels 43 and 46, the absence of liquid metal in the partly solidified casting 8 in the path of the rays results in the detectors being exposed to a higher dose of radiation with a resultant drop in resistance. The detectors 45 and 48 thus generate signals 045 and 048 which are processed to form a breakthrough signal in a manner that will be later described.

The same arrangement may also be used for the generation of a signal when there is a deficiency in the rate of metal supply. In such a case the surface of the pool will fall below the detector level **43** or **46** without leaving a solidified marginal zone. Consequently the resistances of the crystals in the detectors **45** and **48** will in such an event be still lower. Alternatively the detector **28** which monitors the level of the pool may take the place of one of the two detectors **45** or **48**.

The arrangement according to FIG. **3** consists of a transmitting and detecting arrangement **49** for electromagnetic waves, for example, for radar, laser or other beams. In normal operation the level of the pool in the mold **7** will be as indicated by the dashed line at **60**. The electromagnetic beam **66** projected by a transmitter **50** in the direction towards the surface of the pool is reflected at the surface level **60**, and the reflected beam will be situated as indicated by the dashed line **67**. This reflected beam does not affect either of two detectors **51** and **52**. However, if as a result of a deficiency in metal supply the level **60** of the surface of the pool falls to the so-called first critical level indicated by the dashed line **62**, then the beam **66** will be reflected at the surface of the pool in the direction marked **68** and the reflected beam will now fall on the detector **51** with a given angle of incidence. A signal **051** will therefore be generated.

If the surface of the pool continues to fall until it reaches the second critical level **63** then the beam **66** will be reflected at the surface of the pool in the direction **69** and fall on the second detector **52** with a given angle of incidence. When this occurs a signal **052** will therefore be generated.

The same elements will generate the same signals **051** and **052** if the level of the metal in the partly solidified casting falls as the result of a breakthrough of metal. As will be later described the time interval between these signals decides whether they will be processed to form a signal for indicating a breakthrough or a deficiency in metal supply.

Instead of providing transmitting and detecting means for electromagnetic waves, ultrasonic devices could be used in an analogous way.

For the sake of completeness FIG. **3** also shows monitoring means **28** for the level of the pool in the form of a rod source **29** and a detector **30**.

FIGS. **4** and **5** illustrate two methods of generating signals when liquid metal breaks through the crust of the partly solidified casting **8**. a the mold is a secondary cooling zone comprising cooling members **9**. In the regions where breakout of liquid metal could occur, *i.e.* in the zones **75** and **76**, temperature responsive elements **41** and/or fusible members **42** may be provided. Since the temperature responsive elements **41** can monitor only part of the circumference of the casting **8** several such elements are distributed around the casting periphery.

In the event of a breakout of liquid metal some of the temperature responsive elements **41** will be contacted by the flowing liquid metal and they will then generate a signal **041** which will be further discussed with reference to FIG. **16**.

Similarly, any flowing metal will contact some part of the fusible member **42** and cause the generation of a signal **042** which will be further discussed with reference to FIG. **17**. Preferably the fusible members **42** are kept under tension by springs **77** to ensure that the electrical circuit will be actually ruptured when the fusible members melt. For monitoring the entire periphery of the casting in the zone **76** the fusible members may have the form of loops.

FIG. **6** illustrates the method of detecting a deficiency in the rate of metal supply by monitoring the size of the jet **80**. The emission of light by the metal which corresponds to the size of the jet **80** affects the resistance of the cadmium sulphide crystal in a pyrometer **53**. A network associated with this pyrometer transforms this resistance into a proportional voltage. The voltage obtained is therefore a measure of the approximate size of the teeming jet **80** and consequently represents the rate at which metal enters the mold. This voltage is the previously mentioned signal **053** which indicates a deficiency in metal supply.

FIG. **7** illustrates an arrangement for monitoring the size of the teeming jet with the aid of a magnetizing coil **54**. The coil surrounds a gate **82** which extends from the tundish **4** to the level **60** of the pool. An alternating current which flows through the coil **54** varies in magnitude in proportion to the cross section of the metal flowing through the gate in accordance with the eddy current loss experienced in the metal. The current is transformed into a proportional voltage in a discriminator. These voltages may similarly provide the signal **054** which represents a deficiency in metal supply.

FIG. **8** illustrates the circuit in which the signal **045** is processed to form a signal **093** indicating a breakthrough of metal. A current driven by a voltage source **85** in the detector **45** flows through the cadmium sulphide crystal **86** and a resistor **87**. The voltage drop across the resistor **87**, *i.e.* the signal **045**, is fed to a differentiating member **88** which delivers a signal **088**. This signal is applied to a Schmitt comparator circuit **89**. If the signal **088** which has been differentiated with respect to time, rises above a given threshhold **90** (FIG. **9**), *i.e.* if the rate at which the liquid metal surface falls exceeds the threshold **90** which is determined by the rate of withdrawal, then signal **089** will appear in the output of the comparator circuit. In order to make allowance for variations in the rate of withdrawal the theshhold value **90** is preferably arranged to change in accordance with any such variations. The signal **089** is taken to an amplifier **91**. The amplifier output is connected to a storage element in the form of a self-holding relay **92**. The relay is therefore capable of responding to and of retaining the signal **089** which normally appears in the form of a pulse. The signal **093** for indicating the occurrence of a metal breakthrough is generated by the closure of a contact **93** operated by the relay **92**. A cancellation device not shown in the drawing permits this signal **093** to be extinguished.

FIG. **9** is a diagram illustrating the signals as a function of time that are generated by a breakthrough of liquid metal in solid line; the signals due to a deficiency in supply are also plotted in dashed lines for a comparison.

As can be seen from the plot of signals, for clearly indicating a deficiency in metal supply the illustrated arrangement is unsuitable because the rate of change of the signal **045** is then likely to be slow. Under normal casting conditions the rate of change would be nil. A discrimination between the two operating conditions is therefore difficult. In order to overcome this difficulty use is made of a level indicator employing a temperature responsive detector, which incidentally is analogously unable to discriminate between a breakthrough and normal casting conditions because of the presence of the solidified crust on the mold walls. However, clearly differentiable signals indicating a deficient metal supply can be obtained because the rate of change of the signal when the level of the metal pool sinks is still fast enough. The signal generated by the temperature responsive detector is processed in substantially the same way as that described with reference to FIGS. **8** and **9**.

The circuit illustrated in FIG. **10** comprises two detectors **45** and **48**. The detector **48** is in effect exactly equal to the detector **45** which has been described with reference to FIG. **8**. **94** is a source of potential, **95** is a cadmium sulphide crystal and **96** is a resistor. The signals **045** and **048** are each taken to a Schmitt comparator circuit **97** and **99** respectively. A signal **097** or **099** will therefore appear in the output of one of the comparator circuits **97** and **99** whenever one of the signals **045** or **048** exceeds a predetermined threshhold value **105** (FIG. **11**). This threshhold value **105** roughly corresponds to the magnitude of the signal which would be generated by the detector in the presence of a crust and in the absence of liquid metal. A signal **098** or **0100** will appear in the output of the corresponding comparator circuit **98** or **100** when the signal **045** or **048** exceeds a higher threshhold value **106** (FIG. **12**). This latter threshhold **106** roughly corresponds to the magnitude of the signal which the detector would generate in the absence of both a crust and liquid metal. From the magnitudes of the signals generated at the level of the two detectors by

reference to the two threshholds it is possible clearly to differentiate between a breakthrough and a deficiency in metal supply.

The two detectors **45** and **48** must be suitably spaced to ensure that intermediate conditions will not lead to faulty indications.

In the event of a metal breakthrough the signals appearing in the outputs of the two comparator circuits **97** and **99** associated with the lower threshholds consecutively affect an AND-gate **107** which delivers a signal **0107**. This signal is further processed to provide a signal **093** indicating the occurrence of a breakthrough as has been described with reference to FIG. **8**.

If the signals result from a deficiency in metal supply the signals appearing in the outputs of the comparator circuits **98** and **100** associated with the higher threshholds will consecutively affect a second AND-gate **108** which delivers a signal **0108**. In order to avoid the generation of an unwanted deficiency signal when casting begins and ends, a signal **026** representing the absolute minimum level of the metal in the tundish **4** and a blocking signal **0114** are likewise fed to further inputs of the gate **108**.

For generating the signal **0114** a storage element **112** is provided which comprises NEITHER-NOR gates **113** and **114**. The output of gate **113** is taken to the first input of gate **114**, whereas the output of gate **114** is taken, on the one hand, as already mentioned, to one input of the gate **108** and, on the other hand, to the first input of gate **113**. The second input of the gate **114** receives a signal from a NOT gate **115** of which the input receives the signal **020** indicating that casting is in progress. This signal may either be triggered by the operator or it may be given by automatic means, and it continues so long as casting proceeds. The signal **030** from the minimum level of the pool level monitoring means is fed to the second input of the gate **113**. The signal **020** thus serves to trigger the blocking signal **0114**, whereas signal **030** operates to extinguish the blocking signal.

The signal **0108** is further processed to provide the metal deficiency signal **0111** in the same way as described with reference to FIG. **8**, excepting that in the drawing elements **109**, **110** and **111** have been substituted.

The FIGS. **11** and **12** are graphs of the locally generated signals which appear in the event of a breakthrough or a metal deficiency.

FIG. **13** illustrates the generation of fault signals **093**, **0111** from two different levels at which closely consecutive signals (time interval in the order of seconds) **051** and **052** are generated. The signal **051** is applied, on the one hand, to the input of a time delay element **120** and, on the other hand, to the input of a pulse generating element **121**. The signal **052** is applied to a further pulse generating element **122**. The signal **051** therefore appears in the form of a signal **0120** in the output of element **120** after a period of delay **127** (FIG. **15**) and, on the other hand, as a signal **0121** in the form of a pulse of duration **125** (FIG. **14**) in the output of element **121**. Furthermore, the signal **052** appears in the output of element **122** as a signal **0122** in the form of a pulse of duration **126**.

The time **127** comprises the two periods **125** and **126**. The period **126** represent the response time of the relays **92** and **110**.

The period **125** is decisive for discriminating between the type of the fault inasmuch as at a given spacing of the two monitored levels a limiting value for the rate of fall of the metal surface is introduced. This limiting value may with advantage be derived from the rate of withdrawal of the casting because it varies with the casting parameters: quality of the steel, format, casting temperature and so forth. If the signals from the two monitored levels appear consecutively with an intervening interval of say **128** within the period **125**, then this means that the metal level is falling at a rapid rate in relation to the limiting value, *i.e.* the rate of withdrawal, and that there has been a breakthrough of metal. On the other hand, if the interval between the two signals is say **129** and exceeds the period **125**, then this means that the fall of the metal surface is slow in relation to the limiting value, *i.e.* that the rate of supply of metal is insufficient.

The two signals **0121** and **052** are both applied to the input of an AND-gate **124** which delivers a signal **0124**. This signal is further processed to provide the breakthrough signal **093** in the same way as already described with reference to FIG. **10**.

The two signals **0120** and **0122** as well as the signal **026** indicating the absolute minimum level of the metal in the tundish **4** are applied to the three inputs of an AND-gate **123** which delivers a signal **0123**. This signal **0123** is again processed to provide a metal deficiency signal **0111** in the same way as described with reference to FIG. **10**.

The two FIGS. **14** and **15** are graphs illustrating the sequence in time of the signals.

FIG. **16** illustrates the electrical circuit used for the generation of a breakthrough signal **093** from the signal obtained from temperature responsive elements **41**. As soon as one or more of the thermoelements **41** are contacted by liquid metal, a low voltage appears at the input of an amplifier **130**. After amplification this voltage is applied to a Schmitt comparator circuit **131**. A Schmitt comparator circuit has the property of being able to convert a continuously varying voltage, such as that generated by thermoelements, into two different states 0 or 1 by reference to a given coincidence level. A signal **0131** is thus formed in the output of the comparator circuit **131**.

This signal **0131** is further processed to provide the breakthrough signal **093** in the manner described with reference to FIG. **10**.

FIG. **17** illustrates the generation of a breakthrough signal **093** from the response of fusible members **42**. A current is driven by voltage source **132** through a resistor **133** and the fusible members **42**. The input of a contact protection circuit **134** is electrically short-circuited by the fusible members **42** which are connected in parallel. In the event of a breakthrough, as described with reference to FIGS. **4** and **5**, the electrical path through at least one of the fusible members will be at least temporarily broken by the liquid metal. A voltage pulse will therefore be applied to the input of circuit **134** and a signal **0134** will appear in the output. This signal is further processed to provide a breakthrough signal as described with reference to FIG. **10**.

FIG. **18** illustrates the manner in which a signal **053** from the pyrometer **53** is processed to provide a deficiency signal **0111** in conjunction with the signal **030** obtained from the minimum level of the pool level monitoring device. The signal **053** is first applied to a Schmitt comparator circuit **141**. The adjustable reference value of the comparator circuit **141** corresponds to a minimum permissible size of teeming jet when the slide valve **5** is wide open. A signal **0141** appears in the output of the comparator circuit. Moreover, the signal **030** is taken to a time delay element **140** which delivers a signal **0140**. During the time determined by the element **140** the valve has the opportunity of opening fully. The signals **0140**, **0141**, **026** and **0114** are all applied to the inputs of AND-gate **142** which delivers a signal **0142**. This signal **0142** is further processed to provide a deficiency signal **0111** in the same way as described with reference to FIG. **10**.

FIG. **19** illustrates the evaluating circuit for a signal representing the size of the teeming jet obtained by means of the magnetizing coil **54**. An AC voltage is fed to the coil **54** from a source of AC **145** through a resistor **146**. The voltage drop across the resistor **146** is converted into a DC voltage **0148** in a rectifier bridge **147** and a smoothing capacitor **148**. This DC signal **0148** is applied to an amplifier **149** which delivers the signal **054**. This latter signal **054** is fed into the circuit shown in FIG. **18** in place of the signal **053** in order to generate the deficiency signal **0111**.

FIG. **20** illustrates the circuitry in the main safety controller **55** which controls the drive means and the servos regulating the supply of steel. A suitable source of voltage is connected to the terminals **155** and **156**. The diagram represents the state of readiness for operation, *i.e.* the servos **3** and **6** are energised

in position "closed" and the drive means 13, 16 and 18 are without current. Moreover, control elements 160 to 164 for manual control have not been operated.

During the normal casting process the servo 3 or 6 can be operated by controller 25 or 27 respectively through a contact 165 or 166 respectively for setting them into the positions "open" or "closed" according to the level of the metal. Drive member 13 has been started by controller 31 via a contact 167. As soon as the desired length of casting has passed under the cutter unit 14 the drive means 16 and 18 respectively are started in the direction "feed" via a contact 168 and 169 respectively operated by controller 33. As soon as the casting has been cut the drive means 16 and 18 respectively are changed to "return" by a limit switch not shown in the drawings. As soon as the return has been completed another limit switch controls the drive means 16 and 18 respectively to "stop".

Should there be a breakthrough the relay 92 operates, as already described, and closes its contact 93. This causes the breakthrough signal 093 to be delivered, which starts the alarm 56. At the same time a relay 170 is energised which operates contacts 171 to 174. These disconnect the controllers 25, 27, 31 and 33 and render them ineffective. Hence the servos 3 and 6 move into position "closed" and the drive means 13 is stopped. If the cutter is in operation when the breakthrough signal appears, then the drive means 16 is likewise inactivated, whereas the drive means 18 is not affected by the breakthrough signal so that the cutting operation can be completed.

The changeover of the contacts 171 to 174 simultaneously brings the control elements 160 to 164 for manual operation into circuit. The plant is therefore now set up for manual control and the operator can selectably activate the servos 3 and 6 and the drive means 13, 16, 18 by operating the contacts of the control elements 160, 161, 162, 163.

If in the cutting region the casting is not supported by rollers which travel together with the moving casting a cutting operation that has already begun must not be completed if the flame of the cutter would then damage a stationary roller. In order to cope with this situation a roller contact 177 is provided which responds for instance when the roller is excessively heated.

As already described, the relay 110 operates when a deficiency of metal supply occurs and closes a contact 111. The deficiency signal 0111 is thus generated and indicated by the alarm 57. At the same time a relay 175 which operates with delay is energised. After a selectable period of delay, in the course of which a temporary deficiency in supply could be rectified, the relay 175 closes a contact 176. This in turn results in the operation of the relay 170 and the plant is controlled in the same way as when a breakthrough occurs.

In horizontal casting a fall in the level of the metal in the tundish can be monitored for the purpose of generating a breakthrough signal. The breakthrough signal can be used to separate the tundish from the mold by hydraulic actuating means. The liquid steel is then discharged into an emergency vessel located underneath the point of separation.

The above examples describe only several means for generating and using fault signals. However, the invention is not intended to be limited in scope to these solutions, since more precise fault signals can be generated by suitably combining the above described principles. More particularly an arrangement may be provided comprising a rod source and several radiation detectors whereby any changes in the level of the metal can be indicated by making use of the varying signal strengths supplied by the detectors and the time intervals at which consecutive signals appear. Rapid and accurate information relating to the nature of any fault can thus be obtained. For example, a breakthrough may thus be identified in its initial stages from a relatively small change in level. By immediately intensifying the cooling effects such a breakthrough may possibly even be healed in good time. If the change in level is appreciable, that is to say if the breakthrough has had time to progress and is therefore incapable of being healed, then a second breakthrough signal may be arranged to increase the rate of withdrawal sufficiently to permit the billet to be withdrawn from the plant before it has frozen completely tight.

This invention may be variously modified and embodied within the scope of the subjoined claims.

We claim:

1. A method of controlling a continuous casting plant during fault conditions which cause the level of the liquid metal surface in the mold to fall, comprising the steps of issuing an output fault signal which indicates a fall of metal level unusual to normal casting conditions beyond a level limit which is given by normal casting conditions and controlling the plant with this fault signal according to requirements to finish unusual casting conditions, and including the step of generating a breakthrough signal when a breakthrough occurs, said breakthrough being generated when there is a fall of level of liquid metal in the partly solidified casting.

2. A method of controlling a continuous casting plant during fault conditions which cause the level of the liquid metal surface in the mold to fall, comprising the steps of issuing an output fault signal which indicates a fall of metal level unusual to normal casting conditions beyond a level limit which is given by normal casting conditions and controlling the plant with this fault signal according to requirements to finish unusual casting conditions, and including issuing a signal indicating an absolute minimum level of metal in a pouring vessel, which later signal is used for bridging fault signals at the end of the casting operation.

3. A method according to claim 1, wherein a deficiency signal is generated when there is a fall in the level of the liquid metal pool unusual to normal casting conditions.

4. A method according to claim 1, wherein a teeming jet is formed when the liquid metal is poured into the mold, and wherein said deficiency signal is derived according to the size of the teeming jet.

5. A method according to claim 1, wherein said deficiency signal stops the supply of metal to the mold after a period of delay.

6. A method according to claim 1, wherein said continuous casting plant has withdrawing rollers and associated drive means for withdrawing the casting, and wherein said deficiency signal stops the drive means of the withdrawing rollers after a period of delay.

7. A method according to claim 1, wherein said continuous casting plant has a cutting device for cutting the casting, said cutting device being equipped with a synchronizing gear and a traversing gear, and wherein said deficiency signal stops the synchronizing gear of the cutter after a period of delay but permits a proceeding cutting operation to be completed by the traversing gear.

8. A method according to claim 1, wherein said deficiency signal changes over the control of the plant to manual control after a period of delay.