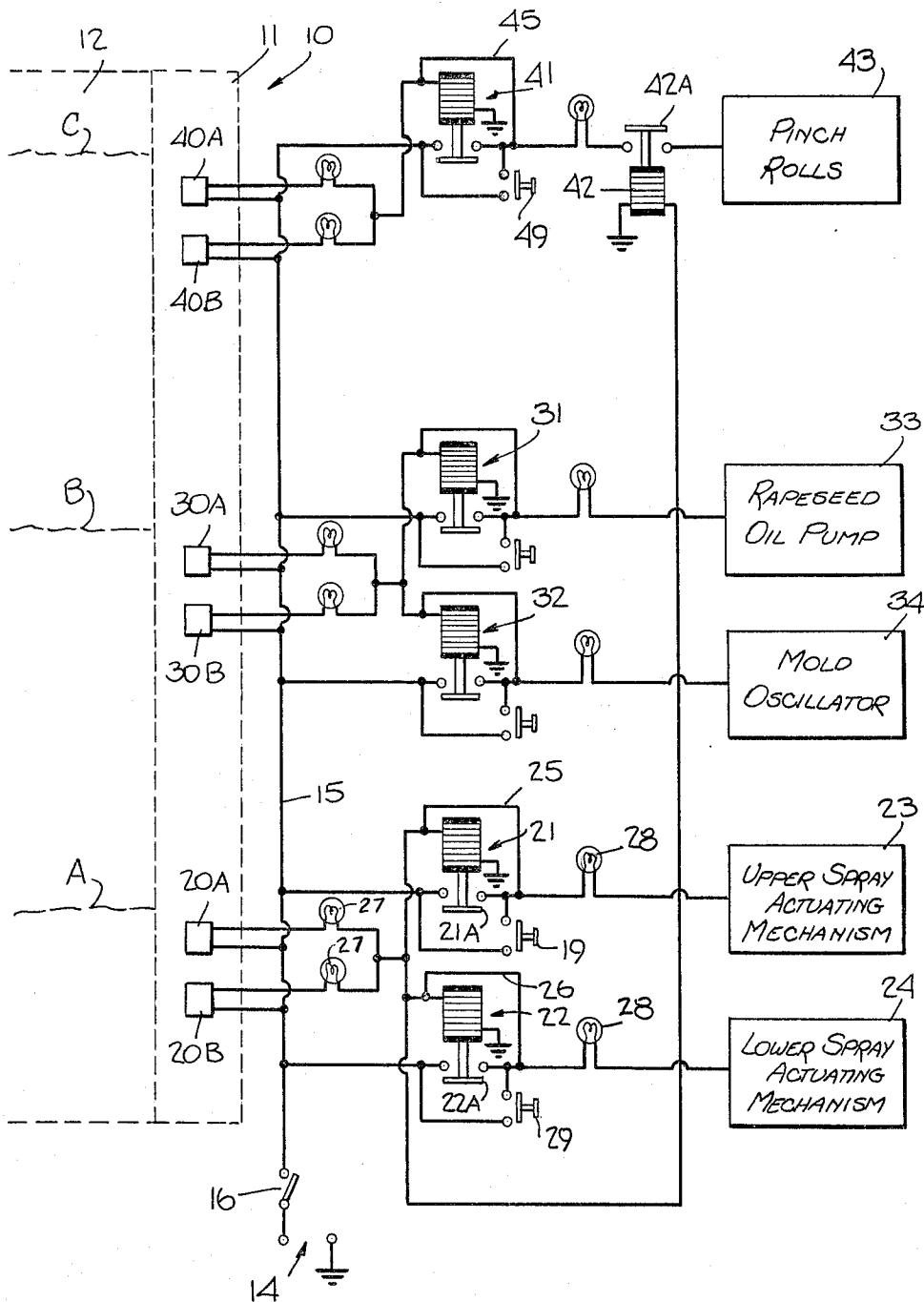


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CONTROL SYSTEM FOR AUTOMATICALLY STARTING
A CONTINUOUS CASTING APPARATUS
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CONTROL SYSTEM FOR AUTOMATICALLY STARTING A CONTINUOUS CASTING APPARATUS

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8 Claims. (Cl. 22—57.2)

This invention relates in general to the continuous casting of metal and more particularly to an electrical control system for automatically starting the continuous casting apparatus.

The control system of this invention includes means for coordinating and timing the starting of the sprays, mold oscillator, oil pump and pinch rolls as a function of liquid level in the mold together with a means to compensate for fast teeming. It is necessary to instrument any automatic system in such a fashion that the design of the mold is not modified and so that the automatic starting system may be readily incorporated into presently existing equipment. Thus it is important that a simple, uncluttered system be provided.

In the continuous casting of metal, a flow-through water-cooled mold is provided to receive molten metal that is teemed from a ladle suspended above the mold. The mold cools the metal to form and partially solidify the casting. Spray units directly spray water on the partially solidified casting as it descends from the mold to further solidify it. When starting a mold run, the spray units are started prior to the start of the withdrawal of the casting from the mold so as to be able to check for spray failures and to note and correct the total water flow. However, it is important that the sprays not be started until after there has been some metal buildup within the mold so that water does not penetrate into the mold to cause a violent eruption. About a 9 inch metal level buildup in the mold is sufficient to keep water from getting into the mold itself.

During operation of the mold it is customary to oscillate the mold longitudinally in order to prevent partially solidified metal from hanging within the mold during withdrawal. In order to avoid fracture of the casting skin, it is desirable to attain full mold oscillation frequency and amplitude by the time the casting starts to be withdrawn from the mold. Since the start-up time of the pinch rolls is much shorter than the start-up time of the mold oscillating apparatus, it is necessary to start mold oscillation prior to starting the pinch rolls. The pinch rolls are started when the liquid level in the mold has reached a pre-determined operating level near the top of the mold. Thus, the oscillator must be started prior to the time when the liquid has reached this operating level. It has been found satisfactory to start the oscillator when the liquid level has reached the mold mid point. The time it takes for the liquid level to build up from the mid point to the operating point is sufficient to assure that the mold oscillator has achieved its full operation prior to the initiation of the withdrawal of the casting by activation of the pinch rolls.

Accordingly, it is a major object of this invention to provide a control system for automatically initiating operation of the casting equipment in the preferred time sequence.

It is a further object of this invention not only to provide the proper sequence between steps that initiate operation of the casting equipment but also to assure that there is an appropriate time delay between steps.

In starting up the continuous casting equipment, it is important that the residence time of the liquid that is initially poured into the mold be long enough so that a

skin is developed which is sufficiently thick and strong as to avoid molten metal break-out when the casting is withdrawn.

Thus it is a further object of this invention to provide an automatic start-up system that includes a means for delaying the start of the pinch rolls until a pre-determined time period after teeming of the liquid from the ladle into the mold starts.

In brief, the control system of this invention involves a series of temperature-responsive relays which are spaced at appropriate intervals along the wall of the continuous casting mold so as to initiate various operations connected with the continuous casting process in the right sequence, the right time intervals and with regard to the liquid level in the mold. A temperature-responsive relay nine inches above the bottom of the mold initiates the operation of the upper and lower sprays. A temperature-responsive relay mid-way along the length of the mold initiates operation of the oil pump and of the mold oscillator. A temperature-responsive relay near the top of the mold normally initiates operation of the pinch rolls. In addition, a time delay relay which is energized by the closing of the relays at the bottom of the mold is in the circuit to the pinch rolls so as to assure that a minimum time will elapse between the start of teeming and the operation of the pinch rolls thereby providing insurance that the casting skin will have become thick enough to prevent metal breakout once the casting starts to be withdrawn.

Other objects and purposes of this invention will become obvious from a consideration of the following detailed description and the drawing, in which:

The figure is an electrical and mechanical schematic of an embodiment of the control system of this invention. With reference to the figure, the electrical control system is shown in association with a continuous-casting mold 10 having a side wall 11 and a through cavity 12 into which the liquid metal is teemed. The liquid metal contained within the mold cavity 12 is shown at three increasing levels designated as A, B, and C.

Positioned within the mold wall 11 and near the bottom thereof is a pair of normally open temperature-responsive relays designated as 20A and 20B. Since these relays 20 are to control the spray units, and since it is desirable to make sure that the liquid in the mold 10 has reached a certain level before the sprays are turned on in order to avoid the possibility of having water enter the mold cavity 12 and cause damage, these relays 20 must be located a short distance above the bottom of the mold. Nine inches from the bottom of the mold has been found to be a suitable distance. Accordingly, the liquid level A, which represents the point where the relays 14 are closed, is about nine inches above the bottom of the mold.

An additional pair of identical relays 30A and 30B are located and similarly positioned at the level B, which is near the mold mid point. In addition, a pair of relays 40A and 40B are located at level C near the top of the mold.

Each of the temperature-responsive relays 20, 30 and 40 is separately connected to the line source 14 by the conductor 15 through a manually operated on-off switch 16. There are two temperature-responsive relays at each position A, B and C solely in order to provide safety through redundancy. Thus, as long as one of the two temperature-responsive relays at each position functions properly, the appropriate operation will commence at the right time. The redundant temperature-responsive relays at each position are shown schematically as above one another. Actually they are at the same level.

With regard to the lowermost relays 20, each of these two temperature-responsive relays 20A and 20B is sepa-

rately and individually connected to the coils of both of the normally open electromagnetic relays 21 and 22. Relay 21 contacts 21A, when closed, connect the actuating mechanism 23 for the upper cooling sprays to the line 14 while relay 22 contacts 22A, when closed, connect the actuating mechanism 24 for the lower cooling sprays to the line source 14. During teeming, when the liquid-metal level in the mold reaches level A, the mold wall 11 adjacent the temperature-responsive relays 20A and 20B reaches a temperature sufficient to operate these relays and thus closes the circuit from the line 14 to the coils of the relays 21 and 22. The coils are then energized and the relay contacts 21A and 22A closed to supply power to the actuating mechanisms 23 and 24 for the upper and lower sprays. Consequently, the sprays begin to operate.

The conductors 25 and 26 operate as a holding mechanism for the relays 21 and 22, respectively, so that once these relays 21, 22 are energized and close, power is supplied to the coils of each relay 21, 22 through the conductors 25, 26, respectively. This insures that the relays 21 and 22 remain energized and their contacts 21A and 22A remain closed after initial energization by the operation of the temperature-responsive relays 20. Thus, the continued operation of the upper sprays and lower sprays is not dependent upon the continued proper operation of the temperature-responsive relays 20. Accordingly, any later change of temperature at the bottom of the mold 10 during its normal operation which might cause the relays 20 to open will not effect the operation of the sprays. Similarly, any temporary variation in the liquid level at the position A during the starting of this continuous casting mold will not cause "chatter" in the operation of the sprays.

The lamps 27 are lit upon the closing of the temperature-responsive relays 20 to provide a visible signal indicating the actuation of these relays. In addition, the lamps 28 are lit upon proper closing of the relay contacts 21A and 22A to provide a visible indication of the operation of the upper and lower sprays. The manually operated on-off switches 29 provide a means for bypassing the temperature-responsive relays 20 to permit operator actuation of the sprays. It should be noted that the switches 29 can be normally open push buttons which may be released as soon as the sprays are actuated since the holding mechanism described above will maintain energization of the sprays after the switches 29 are re-opened. It is to be understood that the lamps 27 and 28, as well as the bypassing switches 29 and the main power switch 16, are located on a central control panel.

The temperature-responsive relays 30A, 30B and the associated control circuits (including the normally open electromagnetic relays 31 and 32) operate in exactly the same fashion as do the relays 20 and associated control circuit. Thus a detailed description of their operation will not be necessary. The temperature-responsive relays 30 are located approximately mid-way along the length of the mold 10. This location is selected with an eye to the location of the temperature-responsive relays 40, which latter relays 40 control the start of the pinch rolls 43. It is desirable that the temperature-responsive relays 30 close to initiate operation of the mold oscillator 34 sufficiently prior to the closing of the relays 40 so as to make sure that the mold oscillator 34 has achieved full oscillation frequency prior to the time the pinch rolls 43 start to withdraw the casting from the mold 10. This time lag between the initial actuation of the pinch rolls 43 and the initial actuation of the mold oscillator 34 is necessary because the start-up time of the pinch rolls 43 is considerably shorter than the start-up time for the mold-oscillating apparatus and it is necessary that the mold be oscillating at its full frequency prior to the time when the pinch rolls start to withdraw the casting in order to avoid fracture of the casting skin within the mold.

It is convenient to initiate the operation of the rape-

seed oil pump 33 at the same time as initiating the operation of the mold oscillator 34 and thus the normally open relay 31, which controls the operation of the rape-seed oil pump 33, is connected in parallel with the normally open relay 32 to be energized by the closing of either one of the temperature-responsive relays 30.

As the molten metal continues to teem into the mold, the liquid level in the mold will rise to the level C, near the top of the mold, and close the temperature-responsive relays 40A, 40B to energize the normally open relay 41 and thereby close a circuit which will initiate operation of the pinch rolls 43 and thus start the withdrawal of the casting from the mold. Again the circuitry associated with the temperature-responsive relays 40 is the same as that described in connection with the temperature-responsive relay 20 (including the holding circuit 45 and manual bypass switch 49) so that further description is not necessary.

However, normally open contacts 42A of a time delay relay 42 are included in the line that leads to the pinch rolls 43 so that the closing of the temperature-responsive relays 40 by itself is insufficient to provide power to the pinch rolls 43. The coil of the time delay relay 42 is connected to the open side of the temperature-responsive relays 20 so that the relay 42 is energized upon the closing of the relays 20 when the liquid level in the mold has reached the position A. The primary function of this time delay relay 42 is to make sure that the metal residence time within the mold 10 has been sufficient to insure the formation of a casting skin of a thickness adequate to prevent metal break-out once withdrawal of the casting starts.

This relay 42 may be pre-set to remain open for whatever period of time is necessary to make sure that the pinch rolls 43 are not operated before a sufficiently thick casting skin has been formed. For example, assume it has been determined that at least 30 seconds should elapse from the time the liquid level in the mold reaches level A and the operation of the pinch rolls begins. Under these circumstances, if the teeming rate becomes extremely rapid and the liquid level reaches level C before the 30 seconds has elapsed, the time delay relay 42 will prevent the operation of the pinch rolls 43 for the desired 30 seconds. It should be noted that the coil of the time delay relay 42 will remain energized as long as power is being supplied to the sprays because the coil of the time delay relay 42 is also connected to the holding circuits 25 and 26. Upon completion of the casting operation, the entire control system may be reset by merely opening the switch 16 which serves to de-energize and consequently open the relays 21, 22, 31, 32, 41 and 42.

The units being controlled, such as the pinch rolls 43, are indicated as "black boxes." It should be understood that these "black boxes" may include the motors and other operative devices which operate the item being designated. Thus in the claims, a reference to the connection between the third control circuit and the pinch rolls, for example, shall be understood to refer to the electrical connection to the motor that powers the pinch rolls or to an actuating mechanism that in turn controls power to the pinch roll motor.

Although one specific embodiment of this invention has been described and illustrated in some detail, it should be obvious that many variations would be possible to those skilled in this art. For example, the redundancy of the temperature-responsive relays at each level is desirable but not essential to the operation of this invention. It is intended, therefore, in the claims to cover all such variations as would be obvious to one skilled in this art.

What is claimed is:

1. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold and a spray unit for cooling said casting; a control sys-

tem for automatically starting the operation of said casting apparatus comprising:

first control circuit means, including a first temperature-responsive relay in the wall of said mold near the bottom of said mold, to control power to said spray unit,

second control circuit means, including a second temperature-responsive relay in said mold wall near the top of said mold, to control power to said pinch rolls, and

time delay means actuated by said first control circuit means and coupled to said second control circuit means to disenable the connection between said second control circuit means and said pinch rolls until a pre-determined time after the actuation of said spray unit.

2. The control system of claim 1 wherein said time delay means includes a normally open time delay relay having its normally open contacts between said second control circuit and said pinch rolls and having its energizing coil coupled to said first control circuit whereby said time delay relay coil is energized when power is first supplied to said spray unit.

3. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold, an oil pump for lubricating the inner surface of said mold, a mold oscillator for longitudinally oscillating said mold, and a spray unit for cooling said casting; a control system for automatically starting the operation of said casting apparatus comprising:

first control circuit means, including a first temperature-responsive relay in the wall of said mold near the bottom of said mold, to control power to said spray unit,

second control circuit means, including a second temperature-responsive relay in the wall of said mold near the mid point along the length of said mold, to control power to said oil pump and to said oscillator,

third control circuit means, including a third temperature-responsive relay in said mold wall near the top of said mold, to control power to said pinch rolls, and

time delay means actuated by said first control circuit means and coupled to said third control circuit means to disenable the connection between said third control circuit means and said pinch rolls until a pre-determined time after the actuation of said spray unit.

4. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold, an oil pump for lubricating the inner surface of said mold, a mold oscillator for longitudinally oscillating said mold, and a spray unit for cooling said casting; a control system for automatically starting the operation of said casting apparatus comprising:

a first control circuit to control power to said spray unit, said first control circuit including a temperature-responsive first relay in the wall of said mold near the bottom of said mold, whereby the presence of molten metal at a level in said mold adjacent to said temperature-responsive first relay will actuate said first relay to supply power to said spray unit,

a second control circuit to control power to said oil pump and to said mold oscillator, said second control circuit including a temperature-responsive second relay in said mold wall near the mid point along said mold, whereby the presence of molten metal at said mid point will actuate said temperature-responsive second relay to supply power to said oil pump and to said oscillator,

a third control circuit to control power to said pinch rolls, said third control circuit including a temperature-responsive third relay in said mold wall near the top of said mold, whereby the presence of molten

metal at a level in said mold adjacent to said third relay will actuate said third relay to supply power to said pinch rolls, and

time delay means actuated by said first control circuit means and coupled to said third control circuit to disenable the connection between said third control circuit and said pinch rolls until a pre-determined time after power is first supplied to said spray unit.

5. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold and a spray unit for cooling said casting; a control system for automatically starting the operation of said casting apparatus comprising:

first control circuit means to control power to said spray unit, said first control circuit means including a first temperature-responsive relay in the wall of said mold near the bottom of said mold, whereby the presence of molten metal at a level in said mold adjacent to said first temperature-responsive relay will actuate said relay to supply power to said spray unit,

second control circuit means to control power to said pinch rolls, said second control circuit means including a second temperature-responsive relay in said mold wall near the top of said mold, whereby the presence of molten metal in said mold adjacent to said second temperature-responsive relay will actuate said second relay to supply power to said pinch rolls, and

a normally open time delay relay having its normally open contacts in the line leading from said second control circuit means to said pinch rolls and having its energizing coil coupled to said first control circuit means whereby said time delay relay coil is energized when power is first supplied to said spray unit,

whereby power will be supplied to said pinch rolls only after both the actuation of said second temperature-responsive relay and the closing of said time delay relay contacts.

6. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold, an oil pump for lubricating the inner surface of said mold, a mold oscillator for longitudinally oscillating said mold, and a spray unit for cooling said casting; a control system for automatically starting the operation of said casting apparatus comprising:

input means adapted to be connected to a source of power,

a temperature-responsive first relay in the wall of said mold near the bottom of said mold, said first relay having normally open contacts in series with said input means,

an electromagnetic second relay having normally open contacts in series between said input means and said spray unit and having its energizing coil in series with said first relay contacts,

a temperature-responsive third relay in said mold wall near the mid point along said mold and having normally open contacts in series with said input means,

an electromagnetic fourth relay having normally open contacts in series between said input means and said oscillator and having its energizing coil in series with said third relay contacts,

an electromagnetic fifth relay having normally open contacts in series between said input means and said pump and having its energizing coil in series with said third relay contacts,

a temperature-responsive sixth relay in said mold wall near the top of said mold and having normally open contacts in series with said input means,

an electromagnetic seventh relay having normally open contacts in series between said input means and said pinch rolls and having its energizing coil in series with said sixth relay contacts, and

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a time delay relay having normally open contacts in series between said seventh relay contacts and said pinch rolls, and having its energizing coil coupled to the input of said spray unit whereby said time delay relay coil is energized when power is first supplied to said spray unit.

7. In a continuous casting apparatus having a casting mold, pinch rolls to withdraw a casting from said mold, an oil pump for lubricating the inner surface of said mold, a mold oscillator for longitudinally oscillating said mold, and a spray unit for cooling said casting; a control system for automatically starting the operation of said casting apparatus comprising:

input means adapted to be connected to a source of power,

a first control circuit to control power to said spray unit, said first control circuit including a normally open temperature-responsive first relay in the wall of said mold near the bottom of said mold, the normally open contacts of said first relay being in series with said input means, said first control circuit further including a normally open electromagnetic second relay having its normally open contacts in series between said input means and said spray means and having its coil in series with the normally open contacts of said first relay, whereby the presence of molten metal at a level in said mold adjacent to said temperature-responsive first relay will close said first relay contacts to energize said second relay coil thereby closing said second relay contacts to energize said spray unit,

a second control circuit to control power to said oil pump and to said oscillator, said second control circuit including a normally open temperature-responsive third relay in the wall of said mold near the mid point along said mold, the normally open contacts of said third relay being in series with said input means, said second control circuit further including a normally open electromagnetic fourth relay having its normally open contacts in series between said input means and said oil pump and having its coil in series with said normally open contacts of said third relay, said second control circuit further including a normally open electromagnetic fifth relay having its normally open contacts in series between said input means and said oscillator and having its coil in series with said normally open contacts of said third relay, whereby the presence of molten

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metal at a level in said mold adjacent to said temperature-responsive third relay will close said third relay contacts to energize said fourth and fifth relay coils thereby closing said fourth and fifth relay contacts to energize said oil pump and said oscillator,

a third control circuit to control power to said pinch rolls, said third control circuit including a normally open temperature-responsive sixth relay in the wall of said mold near the top of said mold, the normally open contacts of said sixth relay being in series with said input means, said third control circuit further including a normally open electromagnetic seventh relay having its normally open contacts in series between said input means and said pinch rolls and having its coil in series with said normally open contacts of said sixth relay, whereby the presence of molten metal at a level in said mold adjacent to said temperature-responsive sixth relay will close said sixth relay contacts to energize said seventh relay coil thereby closing said seventh relay contacts to energize said pinch rolls, and

a normally open time delay relay having its normally open contacts in series between said normally open contacts of said electromagnetic seventh relay and said pinch rolls and having its energizing coil coupled to said first control circuit whereby said time delay relay coil is energized when power is first supplied to said spray unit.

8. The control system of claim 7 further characterized by each of said electromagnetic relays having a holding circuit whereby the closing of said normally open contacts of each of said electromagnetic relays will supply power to the energizing coils of each of said electromagnetic relays thereby maintaining power to each of said units controlled by each of said control circuits regardless of the state of said temperature-responsive relays.

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