

A. J. WHITCOMB ET AL

BLAST FURNACE DISTRIBUTOR CONTROL

Filed Jan. 7, 1941

6 Sheets-Sheet 1

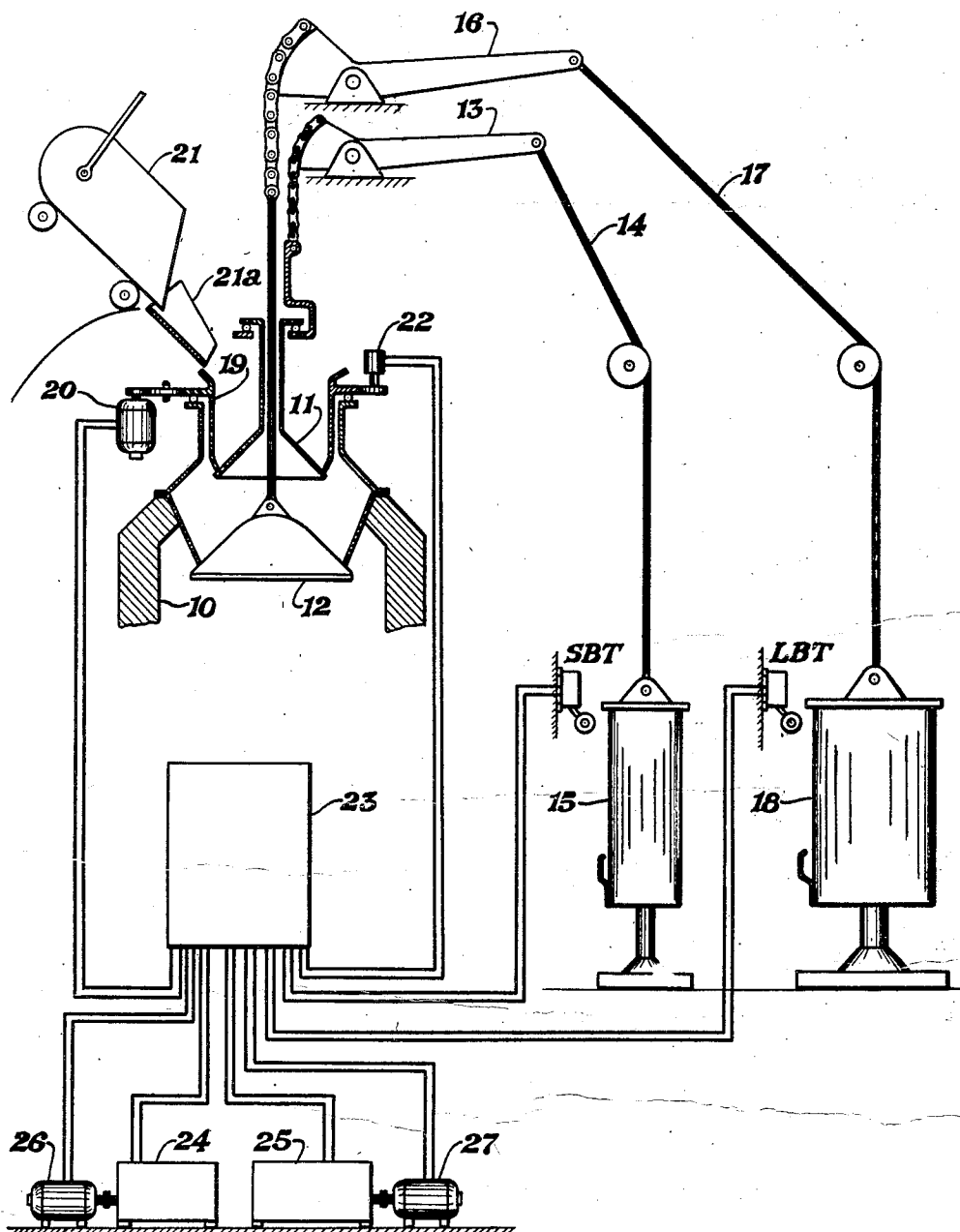


Fig. 1

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June 22, 1943.

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6 Sheets-Sheet 2

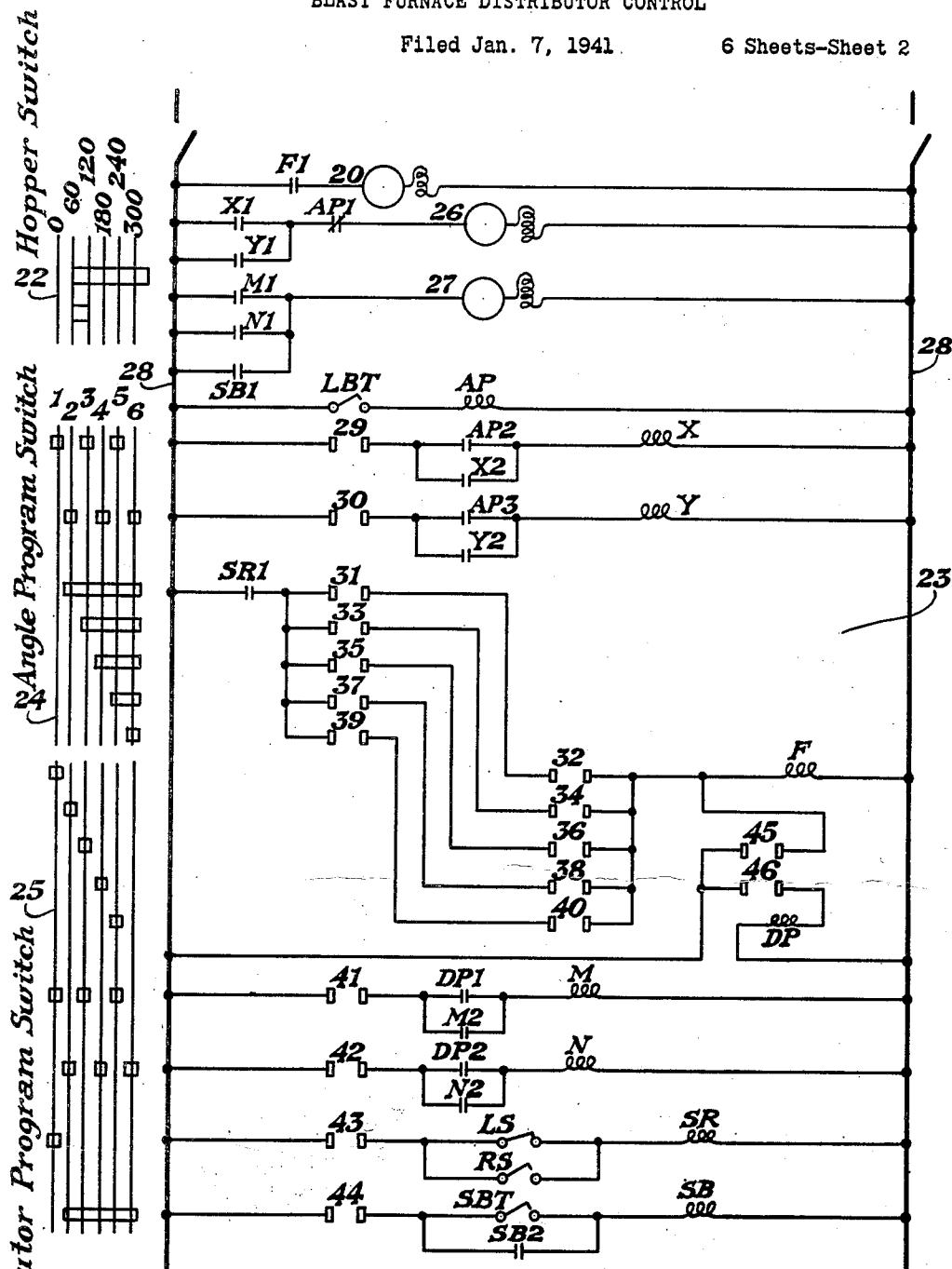


Fig. 2

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6 Sheets-Sheet 3

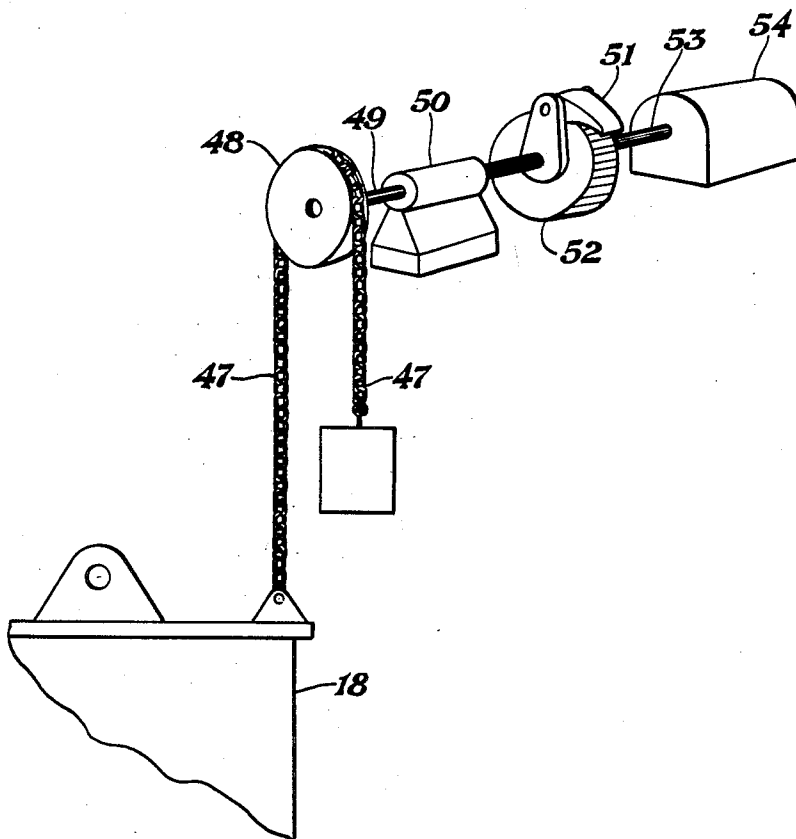


Fig. 3

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6 Sheets-Sheet 4

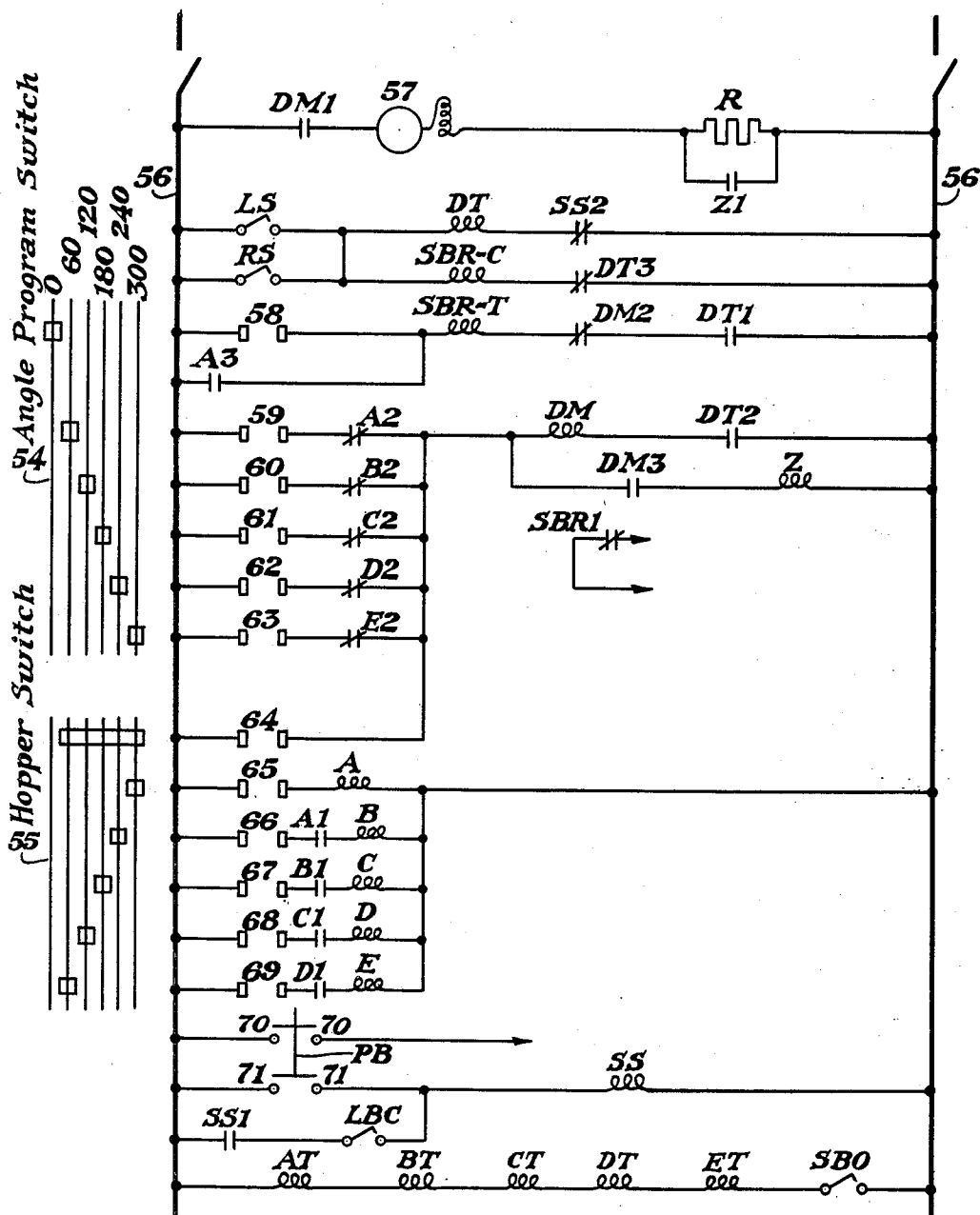


Fig. 4

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6 Sheets-Sheet 5

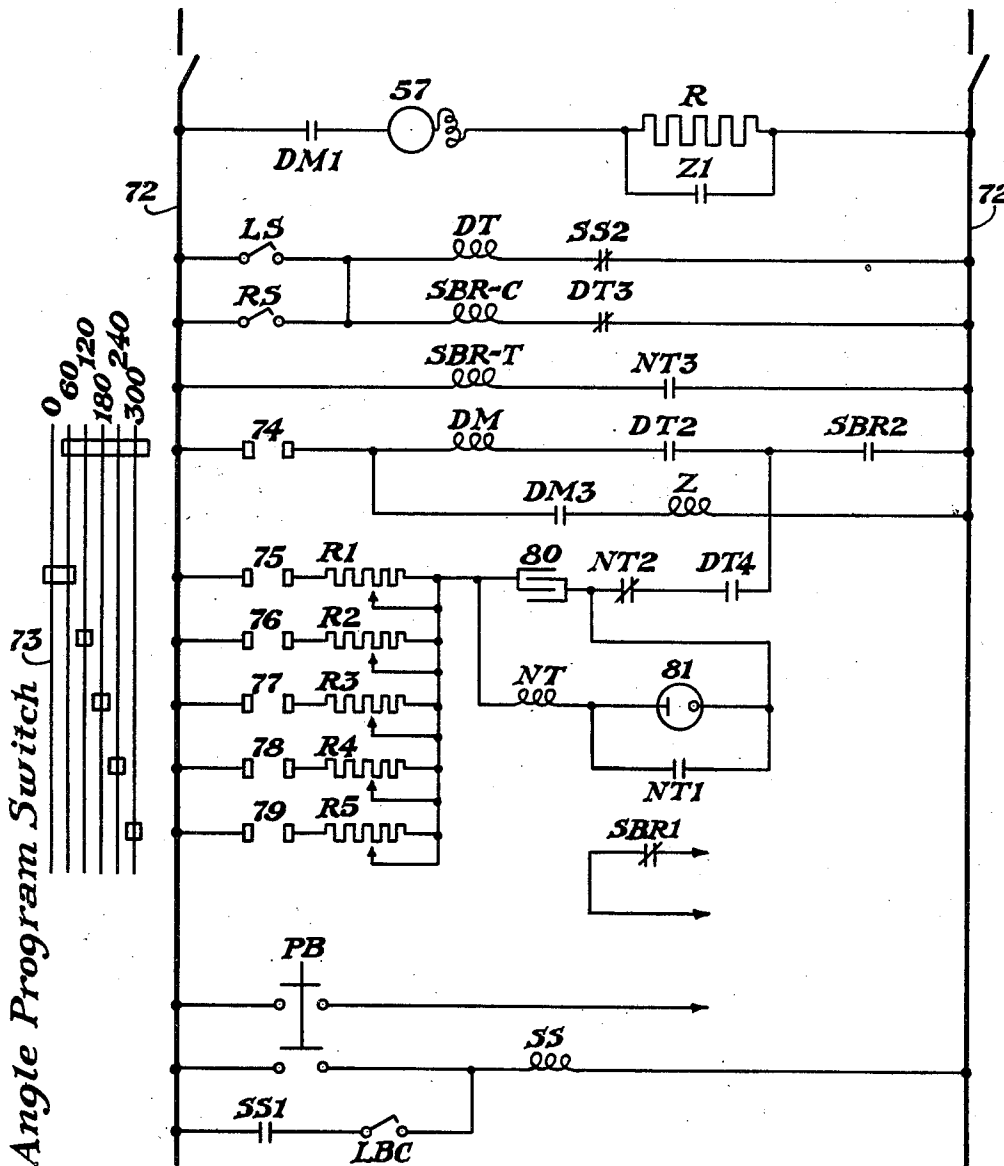


Fig. 5

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6 Sheets-Sheet 6

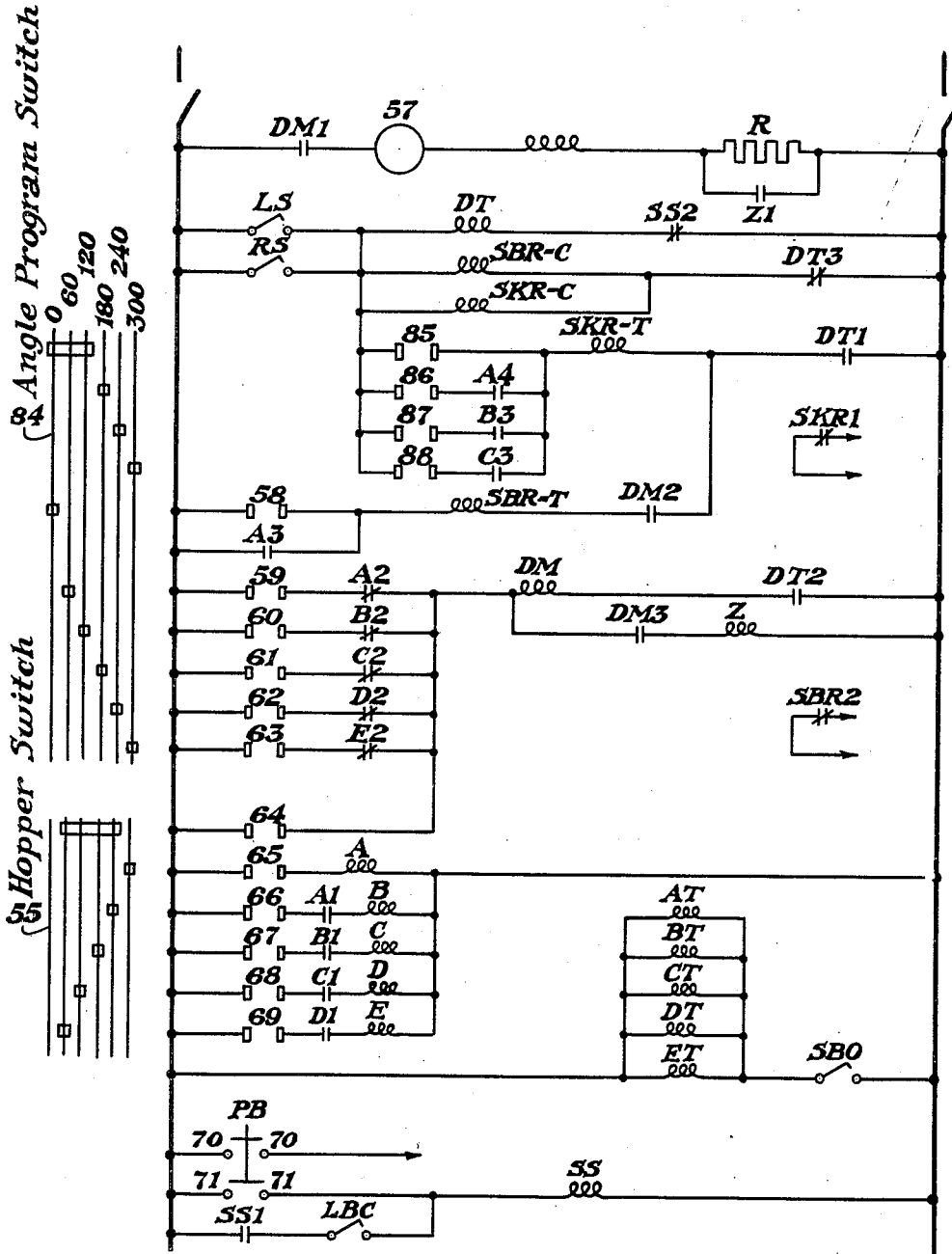


Fig. 6

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UNITED STATES PATENT OFFICE

2,322,406

BLAST FURNACE DISTRIBUTOR CONTROL

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Application January 7, 1941, Serial No. 373,448

16 Claims. (Cl. 214—37)

The present invention relates to improvements in blast furnace distributor controls.

It is desirable in charging a blast furnace to distribute the materials in such a way as to avoid vertical channels therein. Blast furnaces as commonly constructed are charged from a skip hoist, two skips being ordinarily provided, which deliver material alternately into a single discharge conduit, delivering into the distributor hopper at the top of the furnace. The discharge conduit commonly takes the form of an elliptical cone terminating in an approximately circular outlet, the two skips commonly discharging into said conduit adjacent to the ends of the elliptical contour of said conical conduit. The skip outlet has a fixed position relative to the furnace, and inasmuch as the outlet from the conduit discharges downwardly and laterally of the distributor hopper at the top of the furnace, the net effect is that the larger lumps of material are thrown toward that side of the hopper spaced from the skip discharge and the finer material drops more or less vertically toward that side of the hopper adjacent to the skip discharge. Due to the fact that the two skips have their discharging positions disposed adjacent to the two ends of the elliptical contour of the conical discharge conduit, there is a tendency for one of said skips to throw the larger lumps of the material discharged therefrom in a direction disposed angularly with respect to the direction of throw of the larger lumps from the other of said skips. Generally speaking, the effect of the discharges from the skips is to throw the larger lumps of material toward the far side of the hopper and to allow the finer particles to drop to the inner side of the hopper.

An object of the present invention is to provide mechanism for controlling the distributor hopper at the top of a blast furnace whereby the size distribution of the material charged into the furnace may be effectively controlled.

A further object is to provide control mechanism for the distributor hopper of a blast furnace whereby size distribution of the material charged into the furnace may be controlled automatically according to a predetermined plan to avoid vertical channeling.

A further object is to provide distributor control mechanism for insuring that the larger lumps of any particular type of material charged into the furnace will be distributed according to a prearranged plan in successive layers of that type of material and that the larger lumps of the other types of material will be distributed

according to a prearranged plan in successive layers of said other types of material.

A further object is to provide distributor control mechanism for insuring the size distribution above referred to independently of differences in the number of skip discharges which comprise a cycle or a portion of a cycle.

A further object is to provide control mechanism for controlling the rotation of the distributor in relation to the dumps of the large bell, to the end that the distribution of the coarse material and the fine material in any layer may be according to a preferred plan.

A further object is to provide improved distributor mechanism for insuring the desired size distribution of any type of material charged into the furnace regardless of the ratio of the number of dumps of the small bell per dump of the large bell.

A further object is to provide control mechanism for insuring that the coarse lumps and the smaller particles of any material charged into the furnace are symmetrically distributed about the axis of the furnace in a generally helical arrangement.

A further object is to provide a control mechanism in which the changes of angularity of movement of the distributor are had in response to the discharges of the large bell rather than in response to any predetermined number of discharges of the small bell.

A further object is to provide a control mechanism in which suitable distribution of the material can be assured by relatively simple means.

A further object is to provide a control mechanism for a blast furnace charging system in which operation of the distributor hopper and the skip hoist mechanism may be carried out simultaneously without danger that said skip hoist mechanism will reach discharging positions before said hopper is in condition to receive material therefrom.

A further object is to provide distributor control mechanism for improving the performance of a blast furnace.

A further object is to provide distributor control mechanism well adapted to meet the needs of commercial operation.

Further objects will appear as the description proceeds.

Referring to the drawings—

Figure 1 is a diagrammatic view of a blast furnace installation embodying the principles of the present invention;

Figure 2 is a wiring diagram of a distributor

control mechanism which may be used in connection with the disclosure of Figure 1;

Figure 3 is a diagrammatic view of means for providing a step-by-step movement of an angle program switch in response to dumps of the large bell of a blast furnace;

Figure 4 is a wiring diagram showing a modification of the circuits shown in Figure 2;

Figure 5 illustrates another modification; and

Figure 6 illustrates a further modification particularly applicable to the diagram illustrated in Figure 4.

Referring first to Figure 1, a blast furnace is indicated by the numeral 10. At the top of this furnace are the small bell 11 and the large bell 12 arranged in series with one another. Said small bell 11 is controlled by means of the lever 13, which in turn is controlled by the cable 14 adapted to be operated by the small bell operating cylinder 15. The large bell 12 is adapted to be controlled by the lever 16, adapted to be controlled by the cable 17, which is connected to be operated by the large bell cylinder 18. As shown, the small bell cylinder 15 when in its lowermost position holds the small bell 11 in closed position. Likewise the large bell cylinder 18 when in its lowermost position holds the large bell 12 in its closed position. Associated with the small bell cylinder 15 is the limit switch SBT, which is biased to open position and is closed when the small bell operating cylinder 15 is in its uppermost position, that is—when the small bell 11 is fully open. Associated with the large bell operating cylinder 18 is the limit switch LBT, which is biased to open position and is closed when the large bell operating cylinder 18 is in its uppermost position, that is—when the large bell 12 is fully open.

Connected to rotate with the small bell 11 is the hopper 19. A motor 20 is connected to the hopper 19 for communicating a rotative movement to said hopper 19 and small bell 11. One of the two skip tubs of a skip hoist is indicated by the numeral 21. Said skip tubs dump into the chute 21a for discharging downwardly and laterally into the hopper 19.

Adapted to be driven by the hopper 19 is the hopper limit switch 22. According to the control diagram, which will be described presently, the hopper limit switch 22 is adapted to make a complete rotation of 360° while the hopper 19 rotates through an angle of 60°.

The numeral 23 indicates a control panel, the circuits of which may be in accord with the diagrams shown in Figures 2, 4, 5 or 6. The numeral 24 indicates an angle program switch, and the numeral 25 indicates a distributor program switch. The angle program switch 24 is adapted to be driven by the motor 26, and the distributor program switch is adapted to be driven by the motor 27. The connections between the control panel 23, angle program switch 24, distributor program switch 25, hopper limit switch 22, the small bell limit switch SBT and the large bell limit switch LBT will be clear from the discussion of the control diagrams (Figs. 2, 4, 5 and 6), which discussion will appear presently.

Before proceeding with a discussion of the control diagrams, a typical sequence of discharges of material into the blast furnace may be discussed. As indicated above, the present invention has for one of its principal objects the control of the size distribution of each type of material discharged from the large bell into the furnace.

Taking an example from commercial practice, the materials may be charged into the furnace in the following manner: One skipload of ore and two skiploads of coke may be deposited into the hopper, the small bell being opened after the deposit of each skipload thereon. As indicated above, inasmuch as the discharge from the skip hoist is from one side of the blast furnace, the distribution of material is broadly such that the larger lumps go to that side of the hopper distant from the discharge outlet of the skip and the finer particles drop to that side of the hopper adjacent to the skip. After the one skip of ore and the two skips of coke have been deposited in the hopper and in turn have been discharged upon the large bell, the large bell is dumped, communicating the irregular distribution of the larger lumps to one side of the furnace and the finer particles to the other side of the furnace. Proceeding with the example given above, one skip of ore followed by one skip of stone followed by two skips of coke may be discharged into the hopper. After each of these skiploads, the hopper is rotated 60° and the small bell is then opened, discharging the material onto the large bell.

In every instance the large particles discharged from the skip predominate in the region of the hopper distant from the skip incline and the finer particles predominate in the region adjacent to the skip incline.

Since each of the skiploads in the second group was rotated 60° by rotation of the hopper, which rotates as a unit with the small bell, the position of the materials in this group is at a position 60° from the position of the materials in the first group. When the large bell is dumped to deposit these four skips of ore, stone and coke into the furnace the deposition of the coarse lumps and finer particles is angularly displaced, with respect to the deposition of the corresponding lumps of the first group, through an angle of 60°.

The next operation is to discharge one skipload of ore and two skiploads of coke in succession into the hopper. After each deposit into the hopper, the hopper with the small bell is rotated 120° and is discharged onto the large bell. After these three skips have been deposited the large bell is opened to discharge the material into the furnace. The arrangement of large lumps and small lumps in this third layer of material within the furnace is displaced angularly with respect to the first group or layer, an amount equal to 120°, and with respect to the second group or layer an amount equal to 60°. The next deposits of one skip of ore, one skip of stone and two skips of coke in the next group are carried to the 180° position. The deposits in the next group which comprise one skip of ore and two skips of coke are carried to the 240° position with respect to the centerline of furnace. The next deposits comprising one skip of ore, one skip of stone and two skips of coke are carried to the 300° position. The next deposits of one skip of ore and two skips of coke are deposited at the 360° position, which is the zero position from which the typical series was started.

The above described operation accomplishes the result that there is no concentration of coarse lumps at any one side of the furnace nor concentration of finer materials at the other side. The coarse coke of the first coke layer is at the zero position relative to the centerline of furnace, the coarse coke of the next coke layer is at the 60° position, the coarse coke of the next coke

layer is at the 120° position, etc. The same holds true with reference to the ore and with reference to the stone, the stone having been discharged at the 60°, 180° and 300° positions relative to the zero position.

An important feature of the present invention is that the rotation of the hopper and the small bell is controlled in relation to the dumps of the large bell, so that the distribution of the coarse and fine lumps of any material may be symmetrical; that is to say, the desired symmetrical distribution of the coke, for example, is had regardless of the ratio of the number of dumps of the small bell per dump of the large bell. In other words, the coarse lumps and the fines of any material are symmetrically arranged about the vertical axis of the furnace in a distribution which may be termed "generally helical." The changes of angularity in the distribution of material onto the large bell and into the furnace occur in response to the discharges of the large bell and not in response to any predetermined number of discharges of the small bell.

In previous practice, in controlling the charging of blast furnaces, it has been the practice to provide a means to count the discharges of the small bell and to cause the large bell to operate in response to a selected number of such discharges. (Fox et al. Patent No. 1,937,951.) It has also been known to provide separate mechanism to count the discharges of the small bell and to cause the distributor control to operate to change angularity in response to a selected number of such discharges. (Harwood Patents Nos. 1,801,502 and 1,888,501.)

It should be noted with reference to the previously known typical operation that if the angle of rotation were changed after each four skips and consequent four discharges of the small bell, the following grouping would result:

Group 1

One ore, two cokes, one ore.

Group 2

One stone, two cokes, one ore.

Group 3

Two cokes, one ore, one stone.

Group 4

Two cokes, one ore, one coke.

Group 5

One coke, one ore, one stone, one coke.

Group 6

This would be at the 300° position and comprises one coke, one ore and two cokes.

The next group would be at the zero position and would comprise one ore, one stone and two cokes.

As contrasted with the distribution described in previous paragraphs it will be noted that this sort of an operation would lead to what might be called a random distribution.

In the control disclosed herewith only one counting means is necessary since the large bell control may function in response to selected numbers of discharges of the small bell (Patent No. 1,937,951), and the distributor control which is made to respond directly to the large bell may thus indirectly respond to the single counting means instead of two separate counting means. Moreover, as was indicated in the above design-

nated patent, the large bell may open once after a group comprising one number of skiploads, three for instance, and may again discharge after a differing number of skiploads, four for instance.

When the distributor is made to respond to the discharge of the large bell it also responds to the variations in the numbers of skiploads which constitute successive groups, such variation being a significant element of Patent No. 1,937,951. Because of the fact that changes of the angle rotation of the hopper are thus completely kept in a synchronized or symmetrical relationship with the discharges of the large bell, instead of being unrelated thereto, the distribution described in this disclosure may be termed a symmetrical distribution as contrasted with the random distribution which may result from previous practice.

A description of the control diagram of Figure 2 may be prefaced by a short discussion of the hopper limit switch, the angle program switch and the distributor program switch above referred to.

In general, the hopper limit switch measures the movement of the distributor hopper in definite increments (60° increments in the embodiment illustrated) and insures that said hopper will be stopped only at the end of one of these increments of movement.

The angle program switch operates in response to the dumping operations of the large bell. It selects and prescribes the number of 60° increments which comprise each movement of the distributor hopper for one group of small bell discharges constituting one charge upon the large bell. The number of definite increments thus prescribed is changed to each dumping operation of the large bell, or multiple thereof.

The function of the angle program switch disclosed in Figure 5 is similar to that immediately above discussed, except that in the disclosure in Figure 5 the extent of movement of the distributor hopper is determined by allowing prescribed time intervals for said movement.

The distributor program switch operates in response to the movements of the distributor hopper. In general it functions to execute the orders prescribed by the angle program switch. It counts the number of 60° increments of movement traversed by the distributor hopper, and in combination with the hopper switch, it causes the movement of the distributor hopper to cease after said hopper has traversed the number of definite increments prescribed by the angle program switch. The distributor program switch is disclosed only in the modification shown in Figure 2. Its function is accomplished through other means in the modifications illustrated in Figures 4, 5 and 6.

In the system illustrated in Figure 2, several relays are used, which may be described as follows:

The letters AP indicate the operating coil of a relay having the switches AP¹ (biased to closed position), AP² and AP³ (both biased to open position). While coil AP is energized switch AP¹ is open and switches AP² and AP³ are closed.

The letter F indicates the operating coil of a relay having the switch F¹, biased to open position. Energization of the coil F closes switch F¹.

The letter X indicates the operating coil of a relay having the switches X¹ (biased to open position) and X² (biased to open position). While the coil X is energized, switches X¹ and X² are closed.

The letter Y indicates the operating coil of a relay having the switches Y¹ (biased to open position) and Y² (biased to open position). While the coil Y is energized, switches Y¹ and Y² are closed.

The letters DP indicate the operating coil of a relay having the switches DP¹ and DP² (both biased to open position). While coil DP is energized, switches DP¹ and DP² are closed.

The letter M indicates the operating coil of a relay having the switches M¹ and M² (both biased to open position). While coil M is energized, switches M¹ and M² are closed.

The letter N indicates the operating coil of a relay having the switches N¹ and N² (both biased to open position). While coil N is energized, switches N¹ and N² are closed.

The letters SR indicate the operating coil of a relay having the switch SR¹ (biased to open position). While coil SR is energized, switch SR¹ is closed.

The letters SB indicate the operating coil of a relay having the switches SB¹ and SB² (both biased to open position). While coil SB is energized, switches SB¹ and SB² are closed.

In Figure 2 the numerals 28—28 indicate the two sides of an electric circuit. Connected across the circuit 28—28 is the hopper drive motor 20 having armature and series field windings. The connection of the motor 20 to the circuit 28 is controlled by the switch F¹, which switch is responsive to the coil F adapted to be connected across the circuit 28—28 through certain switches controlled by the angle program switch 24 and the distributor program switch 25, to be described presently.

The series motor 26, which drives the angle program switch 24 is also adapted to be connected across the circuit 28—28. The connection of said motor 26 to the circuit 28—28 is controlled by the switch AP¹ (biased to closed position) and by the switch X¹ (biased to open position). In shunting relationship with the switch X¹ is the switch Y¹. Said switches X¹ and Y¹ are controlled by the coils X and Y, respectively, which are responsive to positions of the angle program switch 24, to be described presently.

The motor 27 for driving the distributor program switch 25 is also a series motor. The connection of the motor 27 across the circuit 28—28 is controlled by three switches in parallel with one another, to wit—the switch M¹, the switch N¹ and the switch SB¹. The switch M¹ is responsive to the coil M, the switch N¹ is responsive to the coil N, and the switch SB¹ is responsive to the coil SB. The coils M, N and SB are all responsive to the positions of the program distributor switch 25.

The characters AP indicate a coil whose connection to the circuit 28—28 is responsive to the large bell limit switch LBT, which, as stated above, is adapted to be closed only when the large bell is in its fully open position. The coil AP controls three switches, as follows: AP¹, which is biased to closed position and controls the circuit of the motor 26, as above described; the switch AP²; and the switch AP³. The switches AP² and AP³ are biased to open position. The switch AP² is in circuit with the coil X, above mentioned, and when closed is adapted to connect said coil X across the circuit 28—28, provided the angle program switch 24 is in a predetermined position. The coil X, in addition to operating the switch X¹, as above mentioned, is also adapted

to close the switch X², which is in shunting relationship with the switch AP².

The coil Y above mentioned is adapted to be connected across the circuit 28—28 by the switch AP³ provided the angle program switch is in a predetermined position.

The coil F, above mentioned, which controls the switch F¹ of the hopper drive motor 20 is adapted to be connected across the circuit 28—28 by the switch SR¹ provided the angle program switch 24 and the distributor program switch 25 are in predetermined positions. Said switch SR¹ is responsive to the coil SR, which coil SR is adapted to be connected across the circuit 28—28 when the limit switch LS or the limit switch RS is closed, provided the distributor program switch 25 is in a predetermined position.

The limit switches LS and RS are closed while the left or the right skip tub, respectively, is in the skip pit, which means that the other skip tub is in discharging position. The coil F is also responsive to the hopper limit switch 22, in a manner to be described presently.

The coil SB is adapted to be connected across the circuit 28—28 upon closure of the limit switch SBT, which, as noted above, is closed when the small bell is fully open. Such action occurs, however, only when the distributor program switch 25 is in a predetermined position. Said coil SB, when energized, will close the switch SB¹ and the switch SB². Said switch SB² is in short-circuiting relationship with the limit switch SBT.

In the circuit of the switch AP² and the coil X is the pair of contacts 29. In circuit with the switch AP³ and the coil Y is the pair of contacts 30. In circuit with the switch SR¹ and the coil F are five parallel circuits, of which one circuit includes the pair of contacts 31 and the pair of contacts 32; another circuit includes the pair of contacts 33 and the pair of contacts 34; another circuit includes the pair of contacts 35 and the pair of contacts 36; another circuit includes the pair of contacts 37 and the pair of contacts 38; and the fifth circuit includes the pair of contacts 39 and the pair of contacts 40.

In circuit with the coil M are the switch DP¹ and a pair of contacts 41. Bridging the switch DP¹ is the switch M², which switch M² is biased to open position but is closed when the coil M is energized.

In circuit with the coil N are the switch DP² and the pair of contacts 42. Bridging the switch DP² is the switch N². Said switch N² is biased to open position but is closed when the coil N is energized. The switches DP¹ and DP² are biased to open position but are closed when the coil DP is energized. In the circuit of the coil SR are the limit switches LS and RS, above referred to, which limit switches are in parallel and are alternatively closed when one or the other of the two skip tubs is in the skip pit. In this same circuit are the pair of contacts 43. Said pairs of contacts 29, 30, 31, 33, 35, 37 and 39 are adapted to be bridged selectively in response to the positions of the angle program switch 24. The pairs of contacts 32, 34, 36, 38, 40, 41, 42, 43 and 44 are adapted to be bridged in response to positions of the distributor program switch 25.

The numeral 45 indicates a pair of contacts adapted to connect the coil F across the circuit 28—28. Said contacts 45 are adapted to be bridged in response to positions of the hopper limit switch 22. The coil DP is adapted to be connected across the circuit 28—28 through the

pair of contacts 46, which contacts are adapted to be bridged when the hopper limit switch 22 is in a predetermined position.

The six positions of the angle program switch 24 are indicated by the numerals 1, 2, 3, 4, 5 and 6, and contact members are illustrated in connection with the six positions referred to for selectively bridging the pairs of contacts 29, 30, 31, 33, 35, 37 and 39. Switches for accomplishing this purpose are available to those skilled in the art and need not be described in detail. It may be stated briefly that the pair of contacts 29 are bridged when the angle program switch 24 is in position 1, 3 or 5. The pair of contacts 30 are bridged when the angle program switch 24 is in position 2, 4 or 6. The pair of contacts 31 are bridged when the angle program switch 24 is in position 2, 3, 4, 5 or 6. The contacts 33 are bridged when the angle program switch 24 is in position 3, 4, 5 or 6. The contacts 35 are bridged when the angle program switch 24 is in position 4, 5 or 6. Contacts 37 are bridged when the angle program switch 24 is in position 5 or 6, and the contacts 39 are bridged when the angle program switch 24 is in position 6.

Similarly to the angle program switch 24, the distributor program switch 25 is adapted to bridge the pairs of contacts 32, 34, 36, 38, 40, 41, 42, 43 and 44 under predetermined selected conditions. The contacts 32 are bridged when the distributor program switch 25 is in position 1. The contacts 34 are bridged when the distributor switch is in position 2. Contacts 36 are bridged when the distributor switch 25 is in position 3. Contacts 38 are bridged when the distributor program switch 25 is in position 4, and the contacts 40 are bridged when the distributor program switch 25 is in position 5. Contacts 41 are bridged when the distributor program switch 25 is in position 1, 3 or 5. Contacts 42 are bridged when the distributor program switch 25 is in position 2, 4 or 6. Contacts 43 are bridged when the distributor program switch 25 is in position 1, and contacts 44 are bridged when the distributor program switch 25 is in position 2, 3, 4, 5 or 6.

Contacts 45 are bridged when the hopper limit switch 22 is in any one of the following regions spaced angularly from the zero position, to wit: between 60° and 120°; between 120° and 180°; between 180° and 240°; between 240° and 300°; and between 300° and 360°. Contacts 46 are adapted to be bridged when the hopper limit switch 22 is in the following position spaced angularly from zero position, to wit: between 60° and 120°.

The mode of operation of the circuits illustrated in Figures 1 and 2 is substantially as follows: When the large bell 12 is fully open, the limit switch LBT is closed. Closure of the limit switch LBT results in the energization of the coil AP, resulting in the closing of the normally open switches AP² and AP³, and also resulting in the opening of the normally closed switch AP¹. Under these conditions the angle program switch 24 is in its first position, thereby bridging the contacts 29. Inasmuch as energization of the coil AP has resulted in the closure of the switch AP², the coil X is energized. As soon as the large bell 12 starts to close, the limit switch LBT opens, deenergizing the coil AP and closing the switch AP¹ in the circuit of the motor 26 which drives the angle program switch 24. This motor 26 now runs until the circuit of the coil X is opened, which opening will occur when the angle program switch 24 has moved to position 2. In this

manner the angle program switch 24 is advanced one position each time the large bell is opened.

When one of the skip tubs reaches the skip pit, that is—the end of its travel, one of the limit switches LS or RS is closed, thereby energizing the coil SR, resulting in the closure of the switch SR¹. Switch SR¹ remains closed while either of the skip tubs is in the skip pit, during which interval the entire cycle of operation of the distributor hopper 19 occurs. Closure of the switch SR¹ sets up a group of circuits associated with the angle program switch 24 and with the distributor program switch 25. Since the angle program switch 24 is now in position 2 and the distributor program switch 25 is in position 1, a circuit is established between the conductors 28—28 through the switch SR¹, contacts 31, contacts 32 and the coil F. Energization of the coil F causes the closing of the switch F¹, causing the hopper drive motor 20 to operate, thereby rotating the hopper. Discontinuance of this rotation is governed by the distributor program switch 25 and the hopper limit switch 22, as will be discussed presently.

When the hopper limit switch 22 rotates through an angle of 60°, that is—10° rotation of the hopper, the contacts 45 are bridged, thereby establishing a maintaining circuit for the coil F, insuring that the hopper 19 will continue to rotate at least through one increment of 60°, that is, 360° of the hopper limit switch 22.

The bridging of the contacts 46 by the hopper limit switch 22 establishes a circuit of brief duration through the coil DP, resulting in the closure of the switches DP¹ and DP². Closure of the switch DP¹ establishes a circuit through the coil M, since contacts 41 are bridged by reason of the fact that the distributor program switch 25 is in position 1. Energization of the coil M results in the closure of switch M², establishing a maintaining circuit for the coil M. Energization of coil M also results in the closure of the switch M¹, causing the motor 27 to operate the program switch 25. The motor 27 continues to operate until the circuit of coil M is interrupted by the advancing of the distributor program switch 25 to position 2, in which position the contacts 41 are unbridged.

When the distributor program switch 25 advances to position 2, the circuit of coil F through the contacts 32 is interrupted, resulting in the opening of the switch F¹. The motor 20 driving the hopper 19 will therefore stop after the hopper has made one increment (60°) of rotation, corresponding to 360° rotation of the hopper limit switch 22, causing the parallel maintaining circuit of coil F to be interrupted at the contacts 45, as previously described.

It will be remembered that the angle program switch 24 advances one position each time that the large bell 12 is dumped. If the angle program switch 24 were in position 3, two circuits would be completed to the coil F, to wit—through the contacts 31 and the contacts 32, and through contacts 33 and contacts 34. The first mentioned circuit, that is—through contacts 31 and contacts 32, is completed only when the distributor program switch 25 is in position 1. The other of these two parallel circuits, that is—through contacts 33 and contacts 34, is complete only when the distributor program switch 25 is in position 2. In consequence of these two parallel circuits, coil F is energized (one of the skip tubs being in the pit) while the distributor program switch 25 is in its positions 1 and 2.

Therefore the hopper 19 will be revolved through two 60° increments involving two revolutions of the hopper limit switch 22.

It should be noted that coil F can be energized through two routes. One route involves the contact 31, 33, 35, 37 or 39 and the contact 32, 34, 36, 38 or 40. If only these contacts were employed, the hopper 19 would be revolved only in response to the positions of the angle program switch 24 and the distributor program switch 25, and rotation would be discontinued when the distributor program switch 25 had advanced to a point where it would interrupt contacts 32, 34, 36, 38 and 40 or a portion thereof corresponding to the position of the angle program switch 24. This would not insure that the hopper 19 revolved exactly a 60° increment. Hopper limit switch 22 insures that the hopper drive motor 20, once started, travels through 60° increments and stops only at the end of such increments, which is to say—only when the hopper limit switch 22 is in its zero position. The related positions of the angle program switch 24 and the distributor program switch 25 determine how many 60° increments the hopper 19 will travel before it stops.

It should be noted that there is no provision to energize the coil F when the angle program switch 24 is in its position 1. Consequently the hopper 19 is not rotated under these conditions and the hopper limit switch 22 remains in its zero position. This position 1 of the angle program switch 24 corresponds to the zero angle position of the hopper 19. When the angle program switch 24 is in position 2, the hopper rotates one increment of 60°; when the angle program switch 24 is in position 3, the hopper 19 rotates through two increments of 60° each, making a total of 120° before stopping; when the angle program switch 24 is in position 4, the hopper 19 rotates three increments of 60°, making a total of 180° before it stops; when the angle program switch 24 is in position 5, the hopper 19 rotates through four increments of 60°, equalling 240°, before stopping; when the angle program switch 24 is in position 6, the hopper 19 rotates through five increments of 60°, totaling 300° before it stops.

It was initially assumed that the distributor program switch 25 started from position 1. In counting the increments of rotation of each hopper load of material, the counting according to this description is initiated from the same starting position, that is—with the distributor program switch 25 in its position 1. The distributor program switch 25 is rotated to position 1 after each skipload in the hopper 19 has been properly rotated. This rotation of the distributor program switch 25 can be accomplished in various ways. One way is as follows:

The small bell 11 is discharged after each skipload is deposited thereon, such discharge taking place after the designated rotation of the hopper 19 has been completed. Operation of the small bell 11 may therefore be used to initiate the action which causes the distributor program switch 25 to return to its position 1 prior to discharge of each skipload of material from the hopper 19. If the distributor program switch 25 is in any of its positions 2, 3, 4, 5 or 6 when the small bell 11 reaches its full open position, closure of the small bell limit switch SBT completes a circuit through the coil SB, contacts 44 being bridged at this time. Energization of the coil SB results in the closure of the switch SB¹,

establishing a maintaining circuit for itself until the distributor program switch 25 reaches its position 1. Energization of the coil SB has also resulted in the closure of switch SB¹, causing the motor 27 to rotate the distributor program switch 25 so long as the switch SB¹ remains closed, that is—until the distributor program switch 25 reaches its position 1.

The disclosures of Figures 3, 4 and 5 will now be described.

Figure 3 discloses diagrammatically a structure for operating an angle program switch through a step by step movement through connections with the large bell operating cylinder. Secured to the large bell operating cylinder 18 is the counterweighted chain 47 trained over the sheave 48. Said sheave is attached to the shaft 49 having the bearing 50. Said shaft 49 carries the pawl 51 adapted to cooperate with the ratchet wheel 52. Secured to the ratchet wheel 52 is the shaft 53 adapted to operate the angle program switch 54.

While Figure 2 shows a combination in which the angle program switch is motor driven, and a distributor program switch, also motor driven, is employed in connection with the hopper switch, Figure 4 shows a modification for accomplishing the same result as obtained in the combination disclosed in Figure 2. However, in the combination of Figure 4 the angle program switch is mechanically driven by the large bell mechanism. In the combination of Figure 4 the distributor program switch is omitted, and the angle program switch functions in connection with a modified hopper switch to perform the functions requiring the three special switches in the combination of Figure 2.

Referring now to Figure 4, the numeral 55 indicates a hopper switch, which, similarly to the hopper switch 22 of Figure 2, is driven from the distributing hopper 19. The system disclosed in Figure 4 involves several relays which may be described as follows:

The letters DT indicate the operating coil of a time delay relay having the switches DT¹ and DT² (both biased to open position) and the switch DT³ (biased to closed position). When the coil DT is energized it will operate after a predetermined time interval to close the switches DT¹ and DT² and open the switch DT³.

The letters DM indicate the coil of a relay having the switches DM¹ and DM² (both biased to open position) and the switch DM³ (biased to closed position). While the coil DM is energized the switches DM¹ and DM² will be held closed and the switch DM³ will be held open.

The letters SBR—C and SBR—T indicate, respectively, the closing coil and the trip coil of a latched relay, which coils control the switch SBR¹ (biased to closed position). When coil SBR—C is energized, switch SBR¹ will be opened and latched open. Energization of the trip coil SBR—T will unlatch said switch SBR¹ and allow it to return to its closed position.

The letters SS indicate the operating coil of a relay having the switch SS¹ (biased to open position) and the switch SS² biased to closed position. While the coil SS is energized the switch SS¹ will be held closed and the switch SS² will be held open.

The letter A indicates the closing coil of a latched relay having the switch A¹ (biased to open position), the switch A² (biased to closed position), and the switch A³ (biased to open position). When the coil A is energized it will latch

the switches A¹ and A² in closed position and the switch A³ in open position.

The letter B indicates the closing coil of a relay having the switch B¹ (biased to open position) and the switch B² (biased to closed position). When energized the coil B latches the switch B¹ in closed position and the switch B² in open position.

The letter C indicates the closing coil of a latched relay having the switch C¹ (biased to open position) and the switch C² (biased to closed position). When the coil C is energized the switch C¹ is latched in closed position and the switch C² is latched in open position.

The letter D indicates the operating coil of a relay having the switch D¹ (biased to open position) and the switch D² (biased to closed position). When the coil D is energized the switch D¹ is latched in closed position and the switch D² is latched in open position.

The letter E indicates the closing coil of a relay having the switch E² (biased to closed position). When the coil E is energized it latches the switch E² in open position.

The letters AT, BT, CT, DTT and ET indicate trip coils for the relays of coils A, B, C, D and E, respectively.

The numerals 58, 59, 60, 61, 62 and 63 indicate pairs of contacts adapted to be bridged selectively when the angle program switch 54 is in predetermined positions. It may be explained briefly that contacts 58 are bridged when the angle program switch 54 is in zero position; contacts 59 are bridged when said angle program switch is in the 60° position; contacts 60 are bridged when said angle program switch is in the 120° position; contacts 61 are bridged when the angle program switch is in the 180° position; contacts 62 are bridged when said angle program switch is in the 240° position; and contacts 63 are bridged when said angle program switch is in the 300° position.

The numerals 64, 65, 66, 67, 68 and 69 indicate pairs of contacts adapted to be bridged when the hopper switch 55 is in predetermined positions. It may be explained briefly that contacts 64 are bridged when the hopper switch 55 is in any position except its zero position; contacts 65 are bridged when said hopper switch is in the 300° position; contacts 66 are bridged when said hopper switch is in the 240° position. The letters LBC indicate a limit switch for the large bell 12. Said limit switch LBC is biased to closed position but is open while the large bell is open. The letters SBO indicate a limit switch for the small bell 11. Said limit switch SBO is biased to open position but is closed while the small bell is open.

The numerals 56—56 indicate the two sides of an electric circuit, across which is a circuit including the armature and series field winding of the hopper drive motor 57, which may be connected to the hopper 19 in a manner similar to that illustrated in Figure 1. In the circuit of the motor 57 is the starting resistance R bridged by the normally open switch Z¹. In series with the motor 57 in the circuit across the conductors 56—56 is the normally open switch DM¹.

The reference letters LS and RS indicate limit switches controlled by the skip tubs of the skip hoist (not illustrated). When either the left-hand skip tub or the right-hand skip tub is in the pit, one of these limit switches will be closed. The letters DT indicate a coil controlled by one or the other of the limit switches LS and RS, and in the circuit of the coil DT is the normally closed switch SS². Also controlled

by one or the other of the two limit switches LS and RS is a coil having the reference letters SBR—C for opening the switch SBR¹. In circuit with the coil SBR—C is the normally closed switch DT³.

The letters PB indicate a switch which for convenience may be termed a push button switch. Said switch when closed will inaugurate certain operations which will continue even though the switch is opened at once. Said switch PB is adapted to bridge the pair of contacts 70—70 and the pair of contacts 71—71. When the contacts 70—70 are bridged it will inaugurate the operation of control mechanism for the large bell 12. Instrumentalities for accomplishing this result are known to those skilled in the art and need not be described herein. It is sufficient to state that instrumentalities suitable for the purpose are described and claimed in the Whitcomb Patent No. 1,928,039 and in the Fox and Whitcomb Patent No. 1,937,951. The letters SS indicate the operating coil of a relay having the switch SS¹ biased to open position when the switch PB is moved to bridge contacts 71—71. This action causes the energization of the operating coil SS, resulting in the closure of the switch SS¹ (biased to open position) and the opening of the switch SS² (biased to closed position). When the large bell limit switch LBC is in its closed position, to which it is biased, the switch SS¹ completes a maintaining circuit for the operating coil SS.

Connected across the conductors 56—56 is a circuit including the trip coils AT, BT, CT, DT and ET adapted when energized to trip the switches which were closed by the closing coils A, B, C, D and E, respectively. Said trip coils are connected across the conductors 56—56 through the small bell limit switch SBO, which is biased to open position but is closed when the small bell 11 is open.

In discussing the operation of the control system illustrated in Figure 4, it may be assumed that both the angle program switch 54 and the hopper switch 55 are in their zero positions.

When either the left-hand or the right-hand skip tub enters the skip pit and the other skip tub reaches its upper limit of travel, the limit switch LS or RS will be closed. This causes the coil DT to be energized. As noted above, the relay which includes the coil DT is a time delay relay which functions only after a time interval sufficient to permit the material to be discharged from the skip tub into the hopper 19. After the lapse of the predetermined time interval the coil DT operates to close the switches DT¹ and DT² and to open the switch DT³. Closure of the limit switch LS or RS also results in the energization of the coil SBR—C, resulting in the opening of the switch SBR¹, preventing starting of the skip hoist and also preventing functioning of the small bell 11. After the lapse of the predetermined time interval, switch DT¹ will close, completing a circuit for the coil SBR—T, causing the opening of the switch SBR¹. This condition permits operation of the small bell 11 and/or the skip hoist. It may be noted in this connection that it will be preferred to connect the switch SBR¹ in the same manner as a push button, whereby only momentary closure is necessary to start operations, holding circuits then being established to cause the cycle to be completed. Such holding circuits need not be illustrated herein inasmuch as circuits suitable for the purpose are well

known to those skilled in the art. A suitable circuit is illustrated in the coil SS and the switch SS¹ above referred to.

When the angle program switch 54 is in its zero position it is not desired that the hopper 19 should rotate. It is therefore satisfactory that the small bell 11 shall operate after the time delay allowed for a skip tub to discharge into the hopper 19. Thus when the angle program switch 54 is in its zero position it is possible for the small bell 11 to be operated and for the skip hoist to be operated after each discharge of a skipload into the small bell hopper.

After a predetermined number of skiploads have been discharged into the hopper 19 and have been further discharged by the small bell 11 without rotation of the hopper, it will be desirable to lower the large bell 12 to discharge the material into the furnace. It will be further desirable to change the arrangement so that any additional skiploads will be rotated through the proper angle before the small bell 11 is opened. Let it be assumed that three skiploads have been discharged into the hopper 19 and in turn have been discharged onto the large bell 12 with zero rotation. When the fourth skipload is being hoisted the push button PB is depressed, thereby energizing the coil SS, closing the switch SS¹ and opening the switch SS². As noted above, the energization of the coil SS is maintained as long as the switch LBC is closed by reason of the closure of the switch SS¹.

Inasmuch as switch SS² has been opened, the time delay relay having the coil DT cannot function. The effect is as follows: When the fourth skipload (first skipload of the new series) reaches the top of the furnace, the closing coil SBR—C is energized, causing the switch SBR¹ to open. The trip coil SBR—T cannot be energized until the switch DT¹ is closed, and switch DT¹ cannot close as long as the sequence switch SS² is open. Therefore the switch SBR¹ remains open, preventing the lowering of the small bell 11 or the further starting of the skip hoist until switch SS² is closed.

The operation of the switch PB will also inaugurate operation of the large bell control, as above referred to. When the large bell reaches its full open position, limit switch LBC opens, thereby interrupting the circuit of switch SS¹, interrupting the maintaining circuit for the coil SS, thereby permitting contacts SS² to close. After a brief interval the relay coil DT acts to close the switch DT¹ (conditional upon the switch DM²), thereby energizing the trip coil SBR—T, closing the switch SBR¹, thus again permitting the small bell 11 and the skip hoist to be operated.

Movement of the large bell operating cylinder 18 causes the ratcheting of the angle program switch 54 from the zero position to the 60° position. When the time delay relay having the coil DT had operated to close the switch DT¹, it at the same time caused the closure of the switch DT². Therefore when the angle program switch advanced to its 60° position, this caused the circuit to be completed through the normally closed switch A², through coil DM, thereby closing the switch DM¹ and opening the switch DM². This made it impossible to energize the trip coil SBR—T. Since it is thus impossible to close the contacts SBR¹, the small bell 11 cannot be discharged and the skip hoist cannot again be started while the switch DM² is open, that is—while the distributor hopper 19 is in movement.

When the hopper 19 starts to rotate, its hopper switch 55 also starts to rotate, this hopper switch being mechanically connected to the hopper to make a complete revolution for each 60° of rotation of the hopper 19. When the hopper switch 55 has moved 60° (10° of hopper movement), a circuit is completed through the hopper switch 55 and contacts 54 to energize the coil DM, this circuit being in parallel with the circuit through the angle program switch 54, contacts 59 and the normally closed switch A². When the hopper switch 55 has rotated 300° (50° of hopper movement), a circuit is completed through the closing coil A. This causes closure of the switch A¹ and causes the normally closed switch A² to open. When the normally closed switch A² opens, one circuit for the coil DM is interrupted. However, the parallel circuit through the contacts 54 is maintained through the coil DM until the hopper switch has traveled to its zero position. When this has happened the coil DM is deenergized and the distributor stops.

When the switch DM¹ opens the switch DM² closes, thereby permitting the trip coil SBR—T to be energized. This in turn causes the closure of the switch SBR¹, permitting the small bell 11 to be lowered and the skip hoist to be operated.

After a desired number of skiploads have been discharged into the hopper 19 and have each been rotated 60° from zero position before discharge, it will again become desirable to dump the large bell 12. Again the button PB is depressed. The large bell 12 is dumped, and the angle program switch 54 is advanced to its third position, to wit—the 120° position. When the angle program switch 54 is in its 120° position it sets up a circuit through the normally closed switch B². When in due course the distributor hopper 19 rotates and its hopper switch 55 reaches the 300° position of said hopper switch, the contacts 55 are bridged, energizing the coil A, closing the switch A¹ and opening the switch A². There is no immediate result when the normally closed switch A² is opened, because the circuit involved is already open at another point. However, closure of the switch A¹ sets up a circuit through the closing coil B. This circuit does not become effective until the hopper switch 55 has made one complete rotation through 360° and an additional rotation through 240°. When this happens the circuit for the closing coil B is completed, causing closure of the normally open switch B¹ and opening of the normally closed switch B². As a result of this action the distributor hopper 19 is caused to stop as soon as the hopper switch 55 has reached its zero position. Thus the hopper switch has been turned through two revolutions, giving 120° movement of the distributor hopper 19.

In like manner the distributor hopper is caused to rotate through three, four or five increments of 60° each when the angle program switch 54 is in its 180°, 240° or 300° position, respectively.

It should be noted that switch A¹ moves in unison with switch A², that switch B¹ moves in unison with switch B², that switch C¹ moves in unison with switch C², and that switch D¹ moves in unison with switch D². Switches A¹, B¹, C¹ and D¹ are moved to closing position by means of the closing coil A, B, C or D, respectively, and are latched in said closing positions. Switch E² is also a latched switch, and switches A², B², C², D² and E² are all released from latched position by means of the trip coils AT, BT, CT, DT and ET, respectively. It will be noted that the trip coils

AT, BT, CT, DT and ET are in circuit with the small bell limit switch SBO, which is biased to open position, being closed only when the small bell is in its extreme open position. Since the small bell is opened after each discharge into the hopper, any or all of the switches A¹, B¹, C¹ and D¹, A², B², C², D² and E² are returned to their original positions when the small bell is dumped.

It should be noted that the trip coil SBR—T obtains its circuit through the angle program switch 54 when that switch is in its zero position. When that switch is not in zero position it is necessary that the trip coil SBR—T be energized through a different circuit. This circuit is completed when the switch A² is closed, indicating that the distributor hopper 19 has initiated its rotation. The circuit through coil SBR—T is closed, however, only after switch DM² closes, when motor 57 completes the increment of rotation. It will be recalled that the switch SBR¹ is a permissive relay which permits the small bell 11 and the skip hoist to be started. Thus it will be noted that this permission is not given until the distributor hopper 19 is properly positioned.

In the above discussion reference has been made to the switch PB as a push button switch. This reference is for purposes of convenience only. In many actual installations the equivalent result will be obtained through automatic means associated with the counting mechanism operated by the small bell, so that after the small bell has made a desired number of discharges, a contact of short duration is made, equivalent to the action of a push button. Structures equivalent to a push button are well known to those skilled in the art. For example, the start button 47L appearing in Figure 2 of the Fox and Whitcomb Patent No. 1,937,951, has a function corresponding to the element PB in Figure 4 of the present application.

Referring further to the action of the sequence switches SS¹ and SS² and their operating coil SS, it is the function of said switches to insure that after a desired number of skiploads with a given angle of rotation have been discharged onto the large bell, it becomes impossible to rotate an additional skipload through the same angle which has applied to the skiploads which now rest on the large bell. In other words, rotation of the hopper 19 cannot be initiated until and unless the large bell has been discharged and in connection therewith has advanced the angle program switch 54 through the next increment of rotation. This is an important point, as it prevents improper inclusion of the first skipload in a new series with the skiploads of the previous series.

Proceeding now to a description of the alternative electrical diagram shown in Figure 5, many of the instrumentalities disclosed in Figure 5 are also disclosed in Figure 4. In the system disclosed in Figure 5 the time delay relay having the operating coil DT also includes the switch DT⁴ (biased to open position), as well as the switches DT² and DT³. In the system illustrated in Figure 5 the relay which includes the operating coil DM, though it also includes the switches DM¹ and DM², has no switch corresponding to the switch DM² of Figure 4. In the system of Figure 5 the relay having the operating coil NT also includes the switches NT¹ and NT³ (both biased to open position) and the switch NT² (biased to closed position).

The two sides of the electrical circuit disclosed in Figure 5 are indicated by the numerals 72—72. According to the system disclosed in Figure 5,

the hopper 19 is driven by the motor 57 having the armature and series field windings as in Figure 4. The circuit of said motor is controlled by the switch DM¹. Also in circuit is the resistance R adapted to be cut out by the switch Z¹. In Figure 5 the two limit switches LS and RS are connected in parallel to control the circuit of the coil DT and the normally closed switch SS², as well as the circuit including the closing coil SBR—C and the normally closed switch DT³, as in Figure 4. The trip coil SBR—T is connected across the circuit 72—72 through the normally open switch NT³, which is responsive to the coil NT, to be described presently.

The angle program switch 73 may be moved with a ratcheting movement similar to that disclosed in Figure 3, being moved an increment of 60° for each cycle of movement of the large bell operating cylinder.

Cooperating with the angle program switch 73 are a plurality of pairs of fixed contacts, indicated by the numerals 74, 75, 76, 77, 78 and 79. It will be sufficient to state that the contacts 74 are bridged when the angle program switch 73 is in any one of the angular positions 60, 120, 180, 240, 300, but is unbridged when said angle program switch is in its zero position. The contacts 75 are bridged when the angle program switch 73 is in its zero position or its 60° position. The contacts 76 are bridged when the angle program switch is in its 120° position. The contacts 77 are bridged when the angle program switch is in its 180° position. The contacts 78 are bridged when the angle program switch is in its 240° position, and the contacts 79 are bridged when the angle program switch is in its 300° position.

In circuit across the conductors 72—72 are the contacts 74, the operating coil DM, the switch DT², and the switch SBR², of which the latter is biased to open position and is responsive to the closing coil SBR—C and to the trip coil SBR—T. Bridged across the circuit which includes the coil DM, switch DT² and switch SBR² is a circuit including the switch DM³ and the operating coil Z.

Figure 5 illustrates a combination similar to that illustrated in Figure 4 except that the hopper limit switch is replaced by a time delay device.

According to the system disclosed in Figure 5, a time delay device is provided for giving the hopper 19 time to rotate after each discharge of the skip tub. The particular time delay relay chosen for illustration is a Neo-timer involving a condenser, adjustable resistances, a discharge tube, and certain relays. Such Neo-timer relays are known to those skilled in the art and have been described in the May 1939 issue of the Iron and Steel Engineer, pages 62 to 71, particular reference being had to page 68. For cooperation with such a switch, the variable resistance R¹ is provided in circuit with the contacts 75, the variable resistance R² is in circuit with the contacts 76, the variable resistor R³ is in circuit with the contacts 77, the variable resistor R⁴ is in circuit with the contacts 78, and the variable resistor R⁵ is in circuit with the contacts 79. Said circuits in parallel with one another are connected to the opposite conductor 72 through the condenser 80, the switch NT² (biased to closed position), the switch DT⁴ and the normally open switch SBR². Connected across the condenser 80 is the circuit including the operating coil NT and the break-down discharge tube

81. In bridging relationship with the tube 81 is the switch NT¹ (biased to open position).

Referring to the functions of the system disclosed in Figure 5, it may be assumed that the angle program switch 73 is in its zero position. When either the left-hand or the right-hand skip tub reaches its upper limit of travel the limit switch LS or RS will be closed. Closure of either limit switch LS or RS results in the energization of the coil SBR—C, it being remembered that the normally closed switch DT³ is closed during the time interval before the operating coil DT functions. Therefore the normally closed contacts SBR¹ open, preventing further starting of the skip hoist and also preventing functioning of the small bell. Simultaneously the contacts SBR² close. Closure of the limit switch LS or RS also causes the coil DT to be energized. As noted above, this coil DT is the operating coil of a time-delay relay, which functions only after a time interval sufficient to permit the material to be discharged from a skip tub into the hopper 19. This time-delay relay functions to close the normally open contacts DT⁴ and DT² and to open the normally closed contacts DT³.

When the switch DT⁴ closes, this is a step toward operation of the Neo-timer operating coil NT. In due course, as later explained, this coil NT functions to close the switches NT¹ and NT² and to open switch NT³, all for a short period of time only. Closure of the switch NT³ completes a circuit for the trip coil SBR—T, whereby switch SBR¹ closes. Since switch SBR¹ is closed, the skip hoist and the small bell 11 can be operated.

It may be noted that, as previously stated, the switch DT³ was opened when the relay of the coil DT functioned. Hence the closing coil SBR—C was deenergized, making it possible for the trip coil SBR—T to function, as described in the preceding paragraph.

Thus, when the angle program switch 73 is in its zero position it is possible for the small bell 11 and the skip hoist to be operated after each discharge into the small bell hopper (after a suitable delay for dumping). There is no rotation of the hopper because the circuit of the coil DM is open at the zero position of the angle program switch 73.

The function is slightly different when the angle program switch 73 is in its 60° position (caused by operation of the large bell operating cylinder). When the limit switch LS or RS closes, the relays having the coils SBR—C and DT function as above described. Closure of the switches DT² and SBR² now completes a circuit for the coil DM. Closure of the switch DM¹ causes energization of the motor 57 to rotate the hopper 19. Closure of the switch DM³ energizes the coil Z, closing the switch Z¹, which short-circuits the accelerating resistor R after a slight delay, since the coil Z and switch Z¹ form part of a time-delay contactor.

The previously mentioned closure of the switches SBR² and DT⁴ impressed a voltage upon the condenser 80 through the adjustable resistor R¹. When the voltage on the condenser reaches the break-down voltage of the discharge tube 81, the condenser 80 discharges through the tube and the coil NT. The flow of current through the coil NT causes it to close its switches NT¹ and NT² and to open its switch NT³. Closure of the switch NT¹ closes a discharge circuit for the condenser around the tube 81. The relay comprising the coil NT and the switches NT¹, NT²

and NT³ will remain in this position only momentarily until the condenser voltage reduces to the drop-out voltage thereof when the relay returns to its original position.

As indicated above, the function of the Neo-timer involving the condenser 80 and the tube 81 is to introduce a definite time interval for rotation of the hopper 19. As the speed at which the hopper 19 rotates is substantially constant, the angle of rotation is closely dependent upon the time of rotation. The time for the condenser to charge and build up its voltage to the voltage of the break-down tube 81 is dependent upon the resistance of the resistor R¹. Adjustment of this resistor controls this time period. When in due course the switch NT³ is closed, the trip coil SBR—T is energized. This leads to the opening of the switch SBR². This causes stopping of the hopper drive motor 57 by interrupting the circuit of the coil DM.

When the trip coil SBR—T is energized the switch SBR¹ closes. This condition permits the skip hoist and the small bell 11 to be again started. It is thus seen that after a skip tub reaches the top of its travel and after a dumping time introduced by the relay of the coil DT, the distributor hopper 19 is started into rotation. This rotation continues for a definite time, determined by the Neo-timer, and since rotation is substantially constant, the hopper rotates through a corresponding angle, and at the end of the time, as determined by the Neo-timer, rotation is discontinued and the switch SBR¹ is reset to permit the discharging of the small bell 11 and further starting of the skip hoist mechanism. This cycle is repeated until it is desired to discharge the large bell 12. Movement of the large bell cylinder 18 to effect the discharging of the large bell results in the ratcheting forward of the angle program switch 73 by mechanism such as shown in Figure 3.

To effect the opening of the large bell, the push button PB may be depressed while the skip mechanism is in transit and while the last skipload of a series is being discharged from the small bell. When this button PB is depressed, coil SS is energized, causing switch SS¹ to close and causing switch SS² to open. Opening of the switch SS² interrupts the circuit of the coil DT so that the relay coil DT cannot function. Therefore, when either of the skip tubs of the skip mechanism reaches its limit of travel, switch SBR¹ is opened, so that the small bell cannot be discharged and the skip mechanism cannot be started. Also because the switches DT² and DT⁴ are open, the hopper drive motor 57 cannot be energized to rotate the hopper 19. When the large bell 12 opens and thereby opens the limit switch LBC, the coil SS is deenergized, switch SS² closes, the coil DT is energized and may function, and the cycle may proceed. Thus the proper allocation of the operations of the large bell with respect to the skiploads of material deposited thereon is assured.

When the angle program switch 73 is in its 120° position the functioning of the control mechanism is exactly the same as when in the 60° position except that the resistor R² is in circuit with the Neo-timer of the condenser 80 instead of the resistor R¹. The value of the resistor R² is such that the time of revolution of the hopper 19 is substantially twice as great as when the resistor R¹ was in circuit. Therefore the angle of rotation is twice as great. Correspondingly greater amplitudes of rotation of the

hopper 19 are had when the angle program switch is in its 180° position, the 240° position and the 300° position, the corresponding resistors R³, R⁴ and R⁵ having such values that the discharge tube 81 will break down after the desired time intervals.

Proceeding now with a description of the system illustrated in Figure 6, it may be stated that said system is similar in most respects to the system illustrated in Figure 4 insofar as the operation of the distributor hopper 19 is concerned. Certain changes have been introduced, principally with reference to the timing of the various events. In the structure of Figure 6 a certain amount of time is saved by reason of the fact that the skip hoist mechanism is permitted to start when the distributor hopper has made a partial movement. In other words, the initiation of movement of the skip hoist mechanism is not delayed until the distributor hopper finishes its movement. The point in the hopper movement at which the skip hoist mechanism is permitted to start depends upon the total hopper movement required.

The description of the system illustrated in Figure 6 may be prefaced by the explanation that in the operation of charging a blast furnace, a load of material is loaded into a skip tub at the skip pit. The skip tub is then raised to the top of the furnace, and upon arriving at the top of the furnace the skip tub is tilted, causing the contents to be discharged into the hopper above the small bell. The hopper including the small bell is then rotated through an angle which may be zero, 60°, 120°, 180°, 240° or 300°, as described in connection with the preceding figures. After the hopper has completed the necessary amount of rotation the small bell is caused to open, is held open for a desired pause period, and then closed. The next succeeding skipload of material may then be discharged into the hopper above the small bell.

It should be noted that three actions are involved in sequence, to wit: (a) material is discharged from a skip tub into the distributor hopper; (b) the distributor hopper is revolved through the desired angle; and (c) the small bell is opened, held open, and closed. Each of the operations referred to involves a corresponding time period. To insure that all materials will be discharged from the skip tub, a time allowance is introduced by means of the time delay relay involving the coil DT, as previously described. This relay is commonly set to introduce a time interval in the order of 10 seconds. The time required for the rotation of the distributor hopper varies somewhat in individual cases, but is commonly of the magnitude of 4 seconds for each 60° of rotation. The time required to open and close the small bell is also subject to variation, but is frequently of the magnitude of 8 seconds to open, 4 seconds to pause and 8 seconds to close, making a total for this operation of 8 plus 4 plus 8, equaling 20 seconds.

Obviously the skip hoist cannot be started while a skip tub thereof is being held at the top of the furnace to insure that all materials are discharged therefrom. Therefore it is impossible either to start the skip hoist, to revolve the distributor hopper, or to open the small bell during the period of approximately 10 seconds allocated to the discharge of materials from a skip tub into the distributor hopper. It is physically feasible, however, for the skip hoist to start its movement as soon as the materials have been discharged,

provided the companion skip tub has received its charge of materials in the skip pit. Ordinarily the time required to load material into one skip tub at the skip pit approximates the 10-second interval necessary to insure discharge of material from the skip tub at the top of the furnace.

If movement of the skip hoist is initiated immediately after the unloading of one skip tub and the simultaneous loading of the other skip tub has been completed, a skip tub will be ascending the incline at the side of the furnace at the same time that the distributor hopper is being rotated and while the small bell is subsequently being opened and closed. As it is not desirable that the skip tub discharge into the distributor hopper while the hopper is in rotation or while the small bell is open, it is essential that the rotation of the hopper and the subsequent movement of the small bell be completed before the ascending skip tub starts to discharge. Whether or not this condition exists depends upon the relative times of the simultaneous movements. If movement of the skip hoist is so fast that the ascending skip tub reaches the top of the furnace in less time than is required for the necessary distributor and small bell movement, then there would be a tendency for the skip to discharge into the distributor hopper while the small bell is still open.

In order to avoid such a contingency the skip hoist control of the blast furnace is commonly provided with an interlock, which causes the stopping of a skip tub at a point near the top of the incline before tilting of the skip tub is initiated, and hence before the discharge of the materials is commenced. While this interlocking prevents the undesirable occurrence of discharge of materials upon an open bell, the frequent stopping of a skip tub at the top of the incline is not a very desirable action. To insure that the top movements of the distributor hopper and the small bell will have been completed before a skip tub ascends to the discharge position, various steps can be taken. For instance the movement of the skip can be made so slow that under any circumstances the top movement will be completed within the time required for the skip trip. In some controls the initiation of the skip movement is delayed until after the distributor hopper has completed its rotation. Then the only top action that must occur during the skip trip is the opening and closing of the small bell. This can always be done in less time than is required for the skip trip. Neither of the above expedients is entirely satisfactory, as they both involve a considerable degree of slowing down of the charging operation.

The system illustrated in Figure 6 involves in practice the delaying of the initiation of movement of the skip hoist under special conditions where such delay is essential, avoiding such delaying of the skip hoist in all instances where such delay is not essential.

Typically, a complete trip from the lowermost position of a skip tub to the final dumping position may be said to require about 40 seconds. Of this interval about 7 seconds are required for capsizing the skip tub at the top of the incline. Thus about 33 seconds are required for ascension of the skip tub to the point where capsizing is initiated. As previously stated, the rotation of the distributor hopper requires about 4 seconds per 60° increment, and the complete opening and closing of the small bell requires about 20 seconds. Thus it will be noted that if the distribu-

tor hopper is rotated through 60°, the time necessary for such rotation and for opening and closing of the small bell is 4 seconds plus 20 seconds, equal to 24 seconds. Under these circumstances it is obvious that if a skip tub starts to ascend at the same time that the distributor hopper starts to rotate, the small bell will become closed at the end of 24 seconds, while the ascending skip tub will not start to capsize until 33 seconds have elapsed. This condition is satisfactory. Similarly, for 120° rotation of the distributor hopper, the small bell will be closed after 28 seconds, a satisfactory situation. When the distributor hopper must revolve through 180°, the small bell will be closed after 12 seconds plus 22 seconds, equal to 32 seconds, and a skip tub will start to capsize after 33 seconds. This is too close a race to insure definitely that the small bell will be closed before discharge of material starts. When the hopper must rotate 240° the time required for such rotation is 16 seconds, so that the small bell will not be closed in a period shorter than 16 seconds plus 20 seconds, equal to 36 seconds. Inasmuch as the ascending skip tub starts to capsize after 33 seconds, it is obvious that the discharge of materials will be initiated before the small bell is closed.

The system of control illustrated in Figure 6 is such that when the angle program switch is in such position as to cause rotation of the distributor hopper through zero, 60° or 120°, operation of the skip hoist is permitted to be initiated simultaneously with the initiation of rotation of the distributor hopper. However, when the angle program switch is in position to cause 180° rotation of the hopper, movement of the skip hoist is delayed in order to give the hopper a handicap. When the angle program switch is in position to cause 240° rotation of the hopper, movement of the skip hoist is similarly handicapped, but to a greater degree. When 300° rotation of the distributor hopper is called for, the hopper is given a still greater handicap and the movement of the skip is delayed to a greater extent.

In the system illustrated in Figure 6, an angle program switch is indicated by the numeral 84. The coil SBR—C controls a switch SBR², biased to closed position, which differs from the switch SBR¹ of Figure 4 in that the switch SBR² is permissive only with respect to operation of the small bell. In parallel relationship with the coil SBR—C is the coil SKR—C, which controls the switch SKR¹, biased to closed position. Said switch SKR¹ is permissive with respect to the skip hoist mechanism. Expressed in other language, the switch SBR² permits initiation of the opening and closing movements of the small bell and the switch SKR¹ permits initiation of movements of the skip hoist mechanism.

The letters SKR—T indicate a trip coil for the switch SKR¹. Said trip coil SKR—T is adapted to be energized when either of the skip tubs is at the top of its travel (which results in the closure of the switch LS or the switch RS), provided the angle program switch is in predetermined positions and provided the switch DT¹ is in closed position.

The numerals 85, 86, 87 and 88 indicate, respectively, pairs of contacts adapted to be bridged when the angle program switch 84 is in predetermined positions. It will be sufficient to state that the contacts 85 are adapted to be bridged when the angle program switch is in its zero, 60° or 120° position. The contacts 86 are adapted to be bridged when the angle program switch 84 is

in its 180° position. The contacts 87 are adapted to be bridged when the angle program switch 84 is in its 240° position, and the contacts 88 are adapted to be bridged when the angle program switch is in its 300° position. In bridging relationship with the contacts 85 is a circuit including the contacts 86 and the switch A¹, which is biased to open position and is controlled by the coil A, being closed when the coil A is energized. Also in bridging relationship with the contacts 85 is the circuit including the contacts 87 and the switch B¹, which is biased to open position but is closed when the coil B is energized. Also disposed in bridging relationship with the contacts 85 is the circuit including the contacts 88 and the switch C¹, biased to open position. Said switch C¹ is closed when the coil C is energized.

Figure 6 shows an alternative arrangement of the trip coils AT, BT, CT, DTT and ET, said trip coils being arranged in parallel relationship with one another instead of being arranged in series relationship with one another as shown in Figure 4. Either arrangement is satisfactory.

If the angle program switch 84 is in the zero, 60° or 120° position, the trip coil SKR—T is energized as soon as the time delay relay involving the switch DT¹ has operated. When said relay operates, the switch DT¹ closes. Energization of the trip coil SKR—T allows the switch SKR¹ to close, thereby permitting initiation of movement of the skip hoist mechanism. If the angle program switch 84 is in its 180° position, the trip coil SKR—T is not energized when the timing relay involving the switch DT¹ closes, and therefore the skip hoist is not permitted to start at the same time that the hopper is started. When the hopper has revolved through an angle of 50°, corresponding to 300° movement of the hopper limit switch 55, the contacts 85 are bridged, energizing the operating coil A, thereby closing the switch A¹. Circuit is thereby completed from one side of the circuit 72—72 through either of the limit switches LS or RS through the contacts 86, switch A¹, trip coil SKR—T and switch DT¹ to the other side of said circuit. Energization of the trip coil SKR—T restores switch SKR¹ to its closed position, thereby terminating the prohibition introduced when energization of the coil SKR—C had opened the switch SKR¹. Initiation of movement of the skip hoist is thereby permitted. Thus it will be seen that movement of the skip hoist is delayed until the distributor hopper has traversed about 50° of its rotation. There remain about 130° of rotation of the distributor hopper. This would require about 8.7 seconds, which added to the 20 seconds required for the opening and closing movements of the small bell makes a total of 28.7 seconds, which is safely within the 32 seconds required for ascension of the skip tub.

Similarly, when the angle program switch 84 is in the 240° position, permission for the skip hoist to start is not given until the hopper limit switch is in the 240° position, at which point the contacts 86 are bridged and the coil B is energized, resulting in the closure of the switch B¹, which completes a circuit through one of the limit switches LS or RS, through contacts 87, switch B¹, trip coil SKR—T, and the switch DT¹, to the other conductor 72. This position of the hopper limit switch 55 is reached when the hopper has traveled through 100° of its total of 240° of movement. Similarly, when the angle program switch 84 is in its 300° position the skip hoist is not permitted to start until after the

distributor hopper has made 60° plus 60° plus 30°, equaling 150° of its total of 300° of movement.

With the means disclosed in Figure 6, movement of the skip hoist is delayed only when the angle program switch 54 is in certain positions, and then the delay is only of sufficient magnitude to insure that the small bell will be closed for a reasonable interval before the ascending skip tub reaches the capsizing position. This delay is introduced into the cycle only under certain conditions where such delay is essential, and the delay is minimized to the extent necessary.

It should be noted in Figure 3 that ratchet wheel 52 is mounted directly on the shaft which is driven from the large bell. Moreover, it drives directly angle program switch 54. By interposing a 2:1 gear reduction between wheel 52 and switch 54, the amplitude of rotation of the latter can be reduced so that two movements of the large bell are necessary to advance the angle program switch 60°. With this arrangement the change of amplitude of rotation of the hopper can be made to occur not with every dump of the large bell but with every other dump of the large bell. In some instances the resulting distribution, still symmetrical and helical in character, is thought to be more advantageous. The claims should be construed with reference to arrangements wherein the change of amplitude of hopper rotation responds either directly to the dumps of the large bell or to multiples thereof.

Though certain preferred embodiments of the present invention have been described in detail, many modifications will occur to those skilled in the art. It is intended to cover all such modifications that fall within the scope of the appended claims.

What is claimed is:

1. In combination, a blast furnace having a small bell, a rotary distributor hopper associated with said small bell, a large bell in series with said small bell, and control means for governing the amplitude of the angular rotation of said distributor hopper in response to dumping operations of said large bell.

2. In combination, a blast furnace having a small bell, a large bell in series with said small bell, a rotary distributor hopper cooperating with said small bell, which hopper is adapted to receive material from a side thereof, and means for progressively varying the angular movements of said distributor hopper in response to dumps of said large bell.

3. The method of controlling the distributions of a plurality of types of materials in a blast furnace which materials are delivered in increments in a regular sequence to form groups, which groups are introduced into the furnace in regularly repeated order, which materials are delivered at the top of said furnace with the coarser portion of each increment angularly disposed with relation to the finer portion thereof, which consists in rotating the positions of the coarser portion of any one type of material through angles varied in relation to the groups of increments to insure a regular helical arrangement of said coarser portions of said one type of material.

4. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, control means for insuring that the amplitude of such rotary movement is a definite angular increment or a multiple thereof, and other control means

related to the dumps of the large bell for defining the number of such angular increments comprising each of such rotary movements.

5. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, control means for insuring that the amplitude of such rotary movement is a definite angular increment or a multiple thereof, other control means for defining the number of such angular increments comprising each of such rotary movements, and means responsive to movement of said large bell for governing the amplitudes of such rotary movement.

6. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, a controller switch driven from said distributor hopper, said controller switch being adapted to stop said motive means at definite regions in the rotation of said distributor hopper, a second controller switch for controlling the amplitudes of the rotations of said distributor hopper, and a third controller switch responsive to the positions of said small bell and said distributor hopper for controlling said second controller switch.

7. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, skip hoist mechanism for delivering material to said distributor hopper, switch mechanism for controlling operation of said small bell and said skip hoist mechanism, a controller switch for stopping the rotation of said distributor hopper at definite regions, and means responsive to said large bell for determining the amplitudes of rotation of said distributor hopper, said switch mechanism being responsive to the positions of said hoist mechanism and said large bell.

8. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, skip hoist mechanism for delivering material to said hopper, a controller switch responsive to operations of said large bell for insuring definite angular positions of said distributor hopper, and timing means responsive to said controller switch for determining the amplitudes of rotation of said distributor hopper.

9. In combination, a blast furnace having a distributor hopper including a small bell, and a large bell in series with said small bell, means for rotating said hopper, control means for said rotating means for insuring that said hopper will stop at the end of certain predetermined increments of rotation, said control means being responsive to movements of said large bell.

10. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, means for rotating said hopper, a controller switch responsive to movements of said large bell for determining the angularity of rotation of said hopper, and means responsive to opening movements of said small bell for returning said controller switch to initial position.

11. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said distributor hopper, skip hoist mechanism for delivering material to said hop-

per, switch mechanism responsive to operations of said large bell for insuring definite angular positions of said distributor hopper, and means cooperating with said switch mechanism for delaying the operation of said skip hoist mechanism when necessary to insure that the desired rotation of said hopper and the operation of said small bell is completed before said skip mechanism delivers a skip tub to a position permitting materials to be discharged therefrom.

12. In combination, a blast furnace having a distributor hopper including a small bell and a large bell in series with said small bell, means for rotating said hopper, control means for said rotating means for insuring that said hopper will stop at the end of certain predetermined increments of rotation, skip hoist mechanism, governing means for delaying the initiation of operation of said skip hoist mechanism under predetermined conditions, dependent upon the amount of rotation required of said hopper.

13. In combination, a blast furnace having a distributor hopper including a small bell and a large bell in series with said small bell, means for rotating said hopper, control means for said rotating means for insuring that said hopper will stop at the end of certain predetermined increments of rotation, skip hoist mechanism, governing means for preventing the initiation of operation of said skip hoist mechanism except under predetermined conditions, and means cooperating with said control means for defining said predetermined conditions, said control means being responsive to movements of said large bell.

14. In combination, a blast furnace having a

5 distributor hopper including a small bell, a large bell in series with said small bell, motive means for rotating said hopper, control means for said motive means responsive to movements of said large bell for insuring the positioning of said hopper at definite angular positions, a second control means for said motive means for determining the amplitudes of rotation of said hopper, skip hoist mechanism, and governing means for controlling the initiation of movement of said skip hoist mechanism, said governing means being responsive to said second control means.

15. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, means for rotating said hopper, a controller switch responsive to movements of said large bell for determining the angularity of rotation of said hopper, skip hoist mechanism, and governing means for delaying the initiation of movement of said skip hoist mechanism depending upon the amount of rotation required of said hopper, said governing means being responsive to said controller switch.

16. In combination, a blast furnace having a distributor hopper including a small bell, a large bell in series with said small bell, means for rotating said hopper, means responsive to movements of said large bell for determining the angularity of rotation of said hopper, skip hoist mechanism, and means for delaying the initiation of movement of said skip hoist mechanism in response to said angularity determining means.

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CERTIFICATE OF CORRECTION.

Patent No. 2,322,406.

June 22, 1943.

ARTHUR J. WHITCOMB, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 55, for "Figures" read --Figure--; and second column, line 56, for "or" read --of--; page 3, second column, line 32, for "prescribed" read --prescribes--; line 37, after "changed" insert --in response--; page 7, first column, line 37, for "grogram" read --program--; page 8, second column, line 16, for "swith" read --switch--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of September, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.