July 13, 1965 T. R. SCHUERGER ETAL 3,194,546

MECHANISM AND METHOD FOR CONTROLLING SINTERING

Filed Aug. 29, 1958 3 Sheets-Sheet 1

FIG. 1

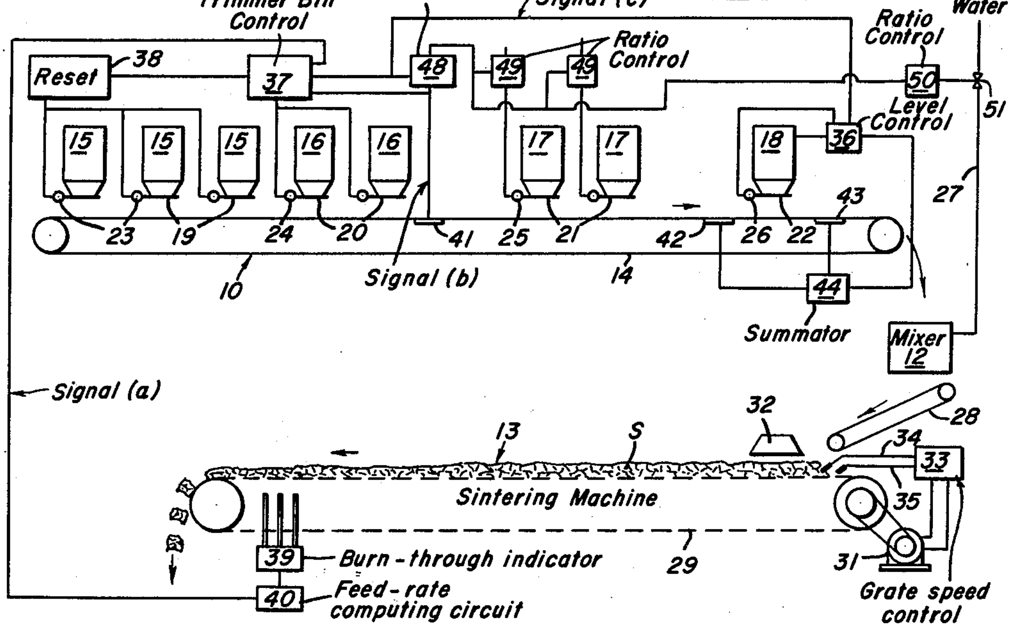
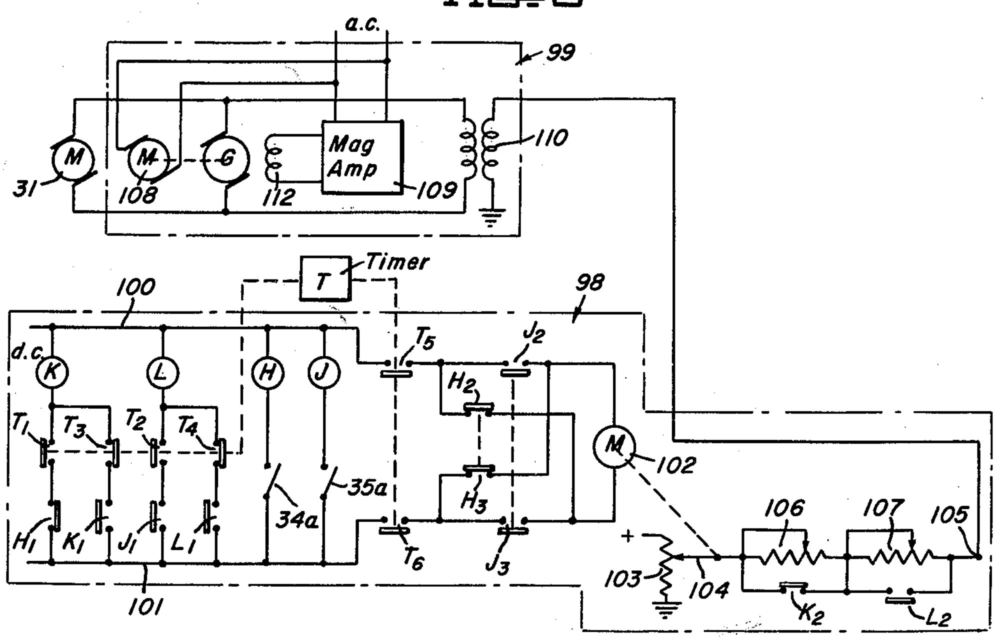


FIG. 5



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MECHANISM AND METHOD FOR CONTROLLING SINTERING

Filed Aug. 29, 1958 3 Sheets-Sheet 2

FIG. 2

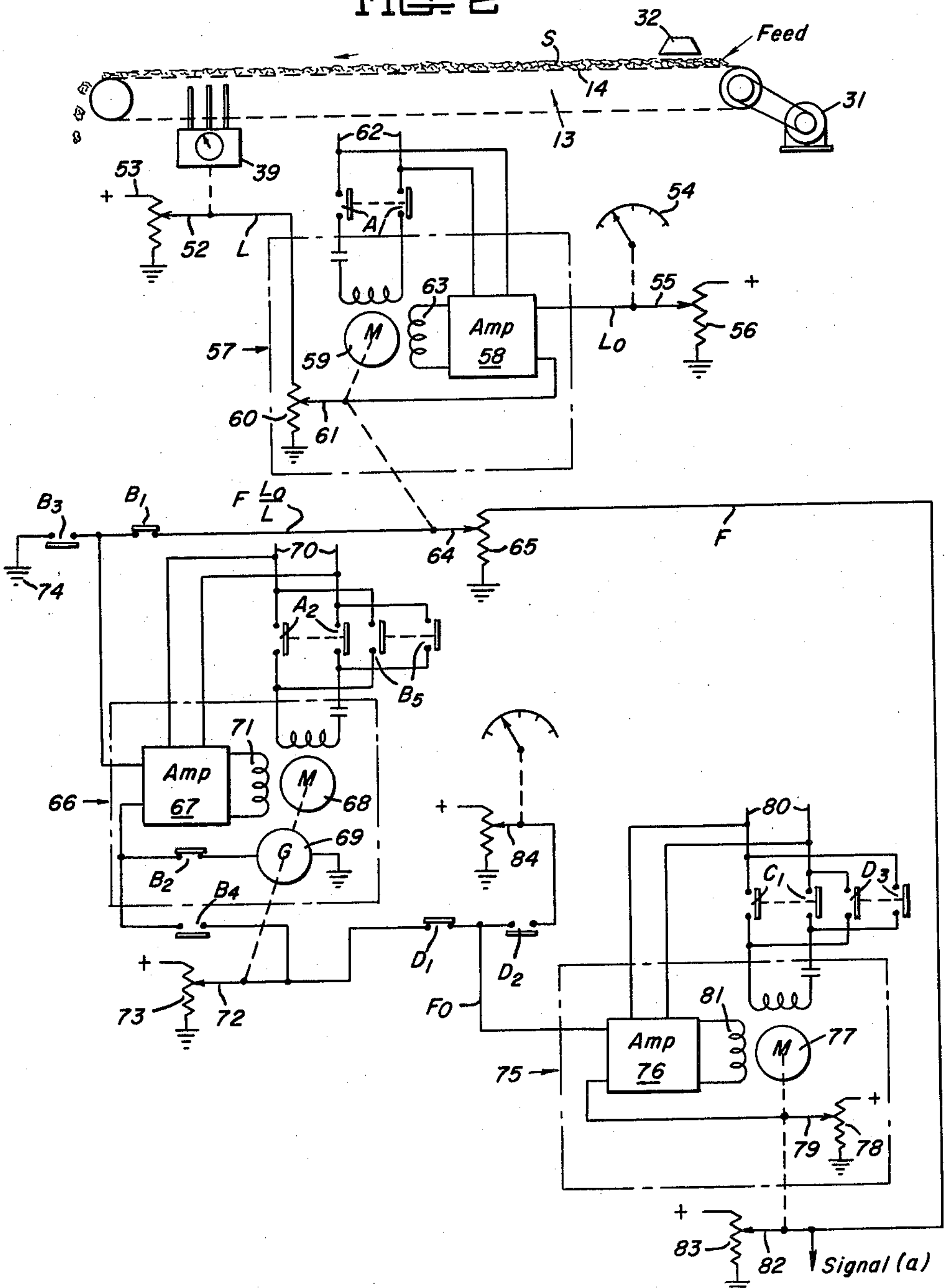

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FIG. 3

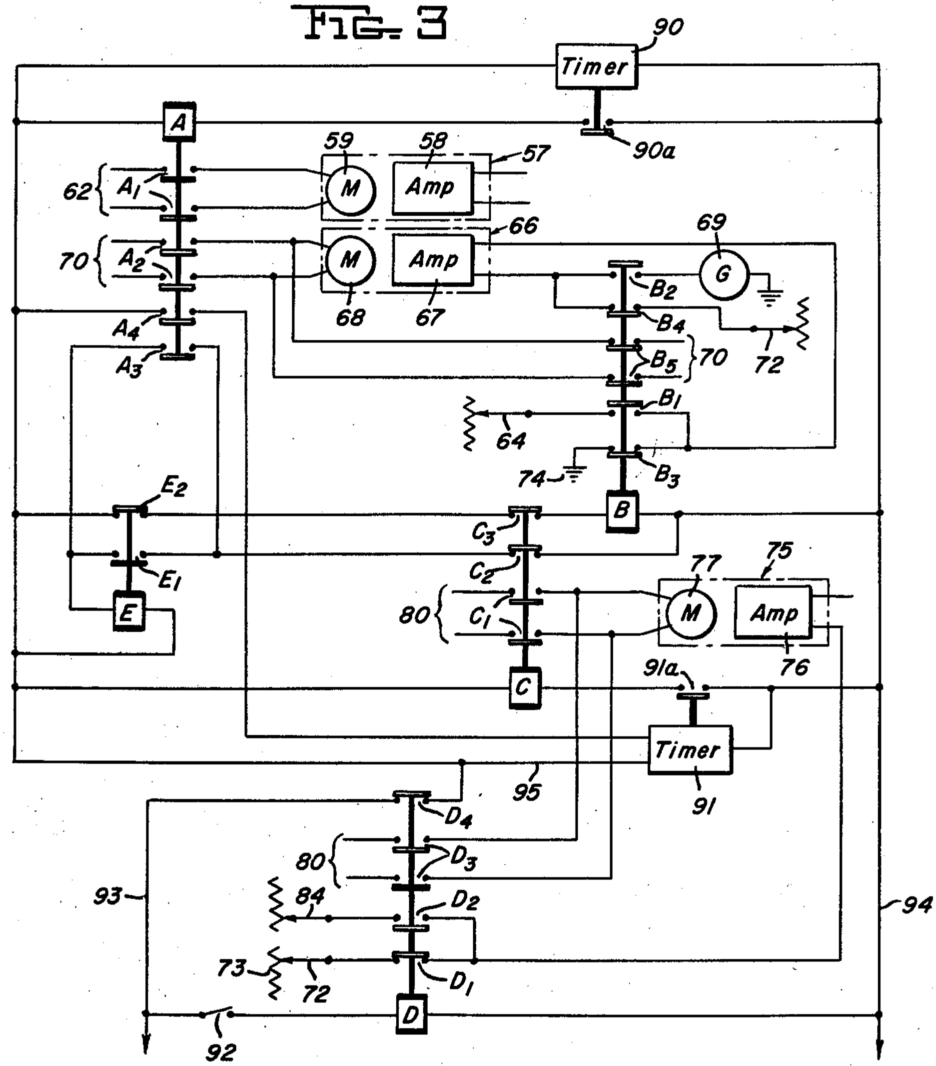
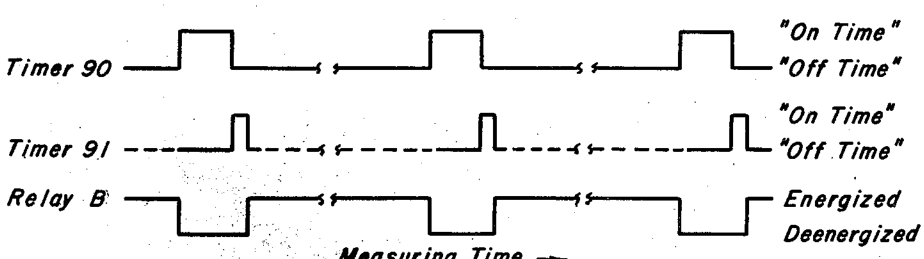


FIG. 4



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United States Patent Office 3,194,546 Patented July 13, 1965

3,194,546

MECHANISM AND METHOD FOR CONTROLLING SINTERING

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Filed Aug. 29, 1958, Ser. No. 758,106
17 Claims. (Cl. 266—21)

This invention relates to an improved mechanism and method for controlling a sintering operation.

In a conventional traveling grate sintering machine, a carefully proportioned combustible mix of metal-bearing particles (for example iron ore), fuel and water feeds to the grate adjacent its entry end. The upper surface of the resulting bed is ignited shortly beyond the line of feeding. Air is drawn or forced downwardly through the bed, and combustion proceeds in a thin zone which slopes downwardly from the line of ignition to a line along the grate, known as the "burn-through" point. For efficient operation the location of the burn-through point must be carefully controlled. If the burn-through point lies too near the discharge end of the grate, the finished sinter contains unburned fuel and is of poor quality. If it lies too far from the discharge end, the full capacity of the machine is not utilized. The location of the burn-through point is a function of grate speed, the rate at which the material burns, and the rate at which material feeds to the grate. An earlier application of George Dykeman jointly with the present co-inventor Schuerger, Serial No. 602,859, filed August 8, 1956 (now Patent No. 2,878,003), discloses and claims an indicator for determining the actual location of the burn-through point. Our earlier application Serial No. 724,688, filed March 28, 1958 (now Patent No. 3,149,192), discloses and claims an apparatus and method for controlling the grate speed to hold the burn-through point at a set location as determined by this indicator.

Conventionally the ingredients of a sinter feed are brought together in a compounding apparatus which includes a main conveyor belt, a series of bins located above the belt and containing the individual ingredients, and table feeders for feeding these ingredients in controlled quantities to the belt. Several bins farthest from the discharge end of the belt usually contain ore fines and equivalents. The next bins usually contain fuel (for example coke and anthracite fines) and other additives. The bin nearest the discharge end usually contains hot fines returned from the sintering machine for recycling. These fines, known as "hot recycle," are another equivalent of ore and must be used approximately as received, except that the bin allows sufficient surge capacity to permit their feeding at uniform rates for extended periods. An earlier application of the present co-inventor Schuerger Serial No. 579,326, filed April 19, 1956, discloses and claims a control method and means applicable to the foregoing type of feed compounding apparatus for automatically proportioning additives and water in accordance with the combined weight of ore and hot recycle, even though hot recycle reaches the belt after the additives. When a change is needed in the hot recycle feed rate, a compensating inverse change first is made in the ore feed rate, whereby the sum of these rates remains constant. Compensating changes in the ore feed rate can be made either by automatic or manual adjustment. In either event the constant sum can be adjusted to regulate the weight of sintered feed produced. The assembled ingredients discharge from the belt to a mixer where water is added, and thence feed to a sintering machine.

Application Serial No. 579,326 was abandoned with

the filing of a continuation-in-part Serial No. 810,508, which issued as Patent No. 2,980,291, April 18, 1961.

The present invention concerns a control mechanism and method in which the weight of material fed to the grate is adjusted automatically to hold the burn-through point at any set location. The grate speed adjusts itself automatically to maintain the depth of bed on the grate within a predetermined range despite varying feed rates. Whenever it is desired to shift the burn-through point to a different location, the setting can be changed, whereupon both the feed rate and grate speed automatically change accordingly. This invention makes use of a burn-through indicator on the sintering machine and controls on the feed compounding apparatus similar to those shown in the foregoing applications, plus suitable computing circuits, whereby the burn-through location directly controls the sum of the rates at which ore and hot recycle feed in the compounding apparatus. In part these circuits are like those shown in our earlier application Serial No. 724,688, except now we control the feed rate directly in accordance with burn-through location and we control grate speed to maintain the depth of the resulting bed on the grate within a predetermined range. In the feed compounding apparatus we also utilize a control for automatically maintaining the level of hot recycle in its bin within a predetermined range, as shown in our earlier application Serial No. 739,870, filed June 4, 1958 (now Patent No. 2,997,205), and preferably an automatic control for the ore feed rate as shown in our earlier application Serial No. 746,261, filed July 2, 1958 (now Patent No. 2,965,265).

An object of the present invention is to provide fully automatic control of a sintering operation, whereby both the rate at which material feeds to a sintering machine and the grate speed adjust themselves automatically to values that hold the burn-through point at any desired location and maintain the depth of bed on the grate within a predetermined range.

A further object is to provide an improved mechanism and method for controlling a sintering operation in which the only manual adjustments are in setting the location of the burn-through point on the grate and in setting the proportions of additives and water, all other variables being automatically controlled for optimum efficiency in accordance with the setting of the burn-through location.

A further object is to provide an improved mechanism and method in which the controls shown in the aforesaid applications are combined to afford completely automated control of a sintering operation.

A more specific object is to provide an improved control mechanism and method for a sintering operation in which a burn-through indicator on a sintering machine is connected through a suitable feed rate computing circuit with an ore feed control on a feed compounding apparatus, whereby the circuit automatically regulates the weight of sinter feed produced and fed to the sintering machine to hold the burn-through point at a set location, and in which the grate speed is automatically regulated to maintain the depth of bed on the grate within a predetermined range.

In accomplishing these and other objects of the invention we have provided improved details of structure, a preferred form of which is shown in the accompanying drawings, in which:

FIGURE 1 is a diagrammatic side elevational view of a sintering installation equipped with control mechanism in accordance with our invention;

FIGURE 2 is a schematic showing of our feed rate computing circuit, the timer circuit being omitted to simplify the illustration;

FIG. 3 is a schematic wiring diagram of the timer circuit for the computing circuit shown in FIGURE 2;

FIGURE 4 is a graph showing the sequence of operation; and

FIGURE 5 is a schematic showing of our grate speed control mechanism.

FIGURE 1 shows diagrammatically a sintering installation which includes a feed compounding apparatus 10, a mixer 12, and a traveling grate sintering machine 13, all conventional apart from our control mechanism. The compounding apparatus comprises a suitably driven main conveyor belt 14, a plurality of ore bins 15, two trimmer ore bins 16, two additive bins 17, and a hot recycle bin 18. The bins 15, 16, 17 and 18 are equipped with table feeders 19, 20, 21 and 22 respectively which have variable speed D.-C. drive motors 23, 24, 25 and 26. Thus the respective ingredients feed from the bins to the belt in quantities individually controlled by regulating the speeds of the table feeder motors. The belt discharges the assembled ingredients to the mixer 12 (for example a pug mill) where water is added via a line 27. A conveyor belt 28 carries the resulting sinter mix to the sintering machine 13 where it forms a bed S. The sintering machine comprises a traveling grate 29, a variable speed D.-C. motor 31 for driving the grate, and an ignition device 32. Motor 31 is equipped with a speed control mechanism 33 actuated by low and high level sensing means 34 and 35 mounted adjacent the feed end of the grate. The control mechanism 33, hereinafter fully described, automatically maintains the grate speed at a value such that the bed depth remains within a range defined by the two sensing means regardless of the feed rate. The sintering machine also includes the usual windboxes, blowers, and other conventional parts, but they are not shown since they are not involved in the present invention.

The feed compounding apparatus 10 is equipped with controls essentially like those shown in Schuerger application Serial No. 579,326, except we have added an automatic control mechanism 36 for motor 26 which drives the hot recycle feeder 22, an automatic control mechanism 37 for motors 24 which drive the trimmer ore bin feeders 20, and a reset mechanism 38 for motors 23 which drive the feeders 19 from the other ore bins. The control mechanism 36 is like that shown in our application Serial No. 739,870, and the mechanisms 37 and 38 like those shown in our application Serial No. 746,261. The sintering machine is equipped with a burn-through indicator 39 like that shown in the Dykeman and Schuerger application. Hereinafter we explain how these devices operate in sufficient detail to impart an understanding of the present invention, but in the interest of conciseness we do not repeat detailed descriptions of individual parts and circuits which appear in the aforesaid applications, and the drawings show these devices only in block diagram.

The rate at which ore feeds to belt 14 from bins 15 and 16 is controlled through three signals proportionate to (a) the desired sum of the ore and hot recycle feed rates, (b) the total weight of ore actually fed to belt 14, and (c) the rate at which the hot recycle feeder is set to operate. Voltages representative of these signals are transmitted to the control mechanism 37 for the trimmer bin feeder motors 24. As shown in application Serial No. 746,261, the mechanism is a magnetic amplifier in which voltages representative of signals (b) and (c) oppose the voltage representative of signal (a). Motors 24 run at a speed proportionate to the resultant voltage. In accordance with the present invention, signal (a) is computed periodically by a feed rate computing circuit 40 controlled by the burn-through indicator 39. This circuit operates on similar principles to that shown in our application Serial No. 724,688, but since the present invention utilizes the signal differently, the circuit is described in detail hereinafter. Signal (b) is derived continuously from a belt scale 41 of conventional construction over which belt 14 passes after the ore has fed thereto.

An example of a suitable belt scale is shown in Frazel Patent No. 2,664,286. The Frazel scale transmits a pneumatic pressure signal which can be converted into a proportionate voltage signal through a suitable transducer, such as shown in Carlson Patent No. 2,059,549. Signal (c) is computed periodically by the hot recycle feed control mechanism 36.

The ore feed rate is regulated to maintain the sum of the ore feed rate and the hot recycle setting at a value determined by signal (a). The sum remains constant between successive computations of this signal. Any change in signals (a) or (c) necessitates a change in the ore feed rate. As long as only routine adjustments are needed in the ore feed rate, the control mechanism 37 continuously regulates the speed of motors 24 and hence changes only the rate at which ore feeds from the trimmer bins 16. Normally motors 23 run at constant speed, whereby ore feeds at a constant rate from the other bins 15. When an unusually large adjustment is needed in the ore feed rate, the control mechanism 37 actuates the reset mechanism 38. Thereupon the reset mechanism periodically changes the speed of motors 23 until the feed rate from bins 15 reaches a value at which the trimmer bins alone can handle necessary adjustments in the total ore feed rate. Occasionally the weight of ore reaching belt 14 may change even though the speed of the feeder motors 23 and 24 does not change. The resulting change in signal (b) immediately corrects the speed of motors 24 accordingly.

Periodically the hot recycle control mechanism 36 computes a new speed for motor 26, which drives the feeder 22 on the hot recycle bin 18. If the level of hot recycle in the bin is within a predetermined range, the new speed equals the instant speed, or the instant speed with a temporary increment discontinued. If the level is outside the range, the new speed equals the algebraic sum of the instant speed, a temporary increment (positive or negative) to return the level to the predetermined range, and a permanent increment (positive or negative) to hold the level within this range after it has returned. Signal (c) is representative of the computed new speed. If the new speed differs from the instant speed, the control mechanism 37 immediately changes the ore feed rate inversely to the change indicated in the hot recycle feed rate, and thus maintains the sum at the value determined by signal (a). After a delay sufficient for belt 14 to carry the changed quantity of ore opposite the hot recycle bin 18, the computed new speed is applied to motor 26. Belt 14 runs over conventional belt scales 42 and 43 immediately before and after hot recycle feeds thereto. The difference in weights which these scales register represents the actual weight of hot recycle fed to the belt. The scales are connected to an algebraic summator 44 which continuously determines this difference. The result is applied to the control mechanism 36 for calibration purposes.

Signals (b) and (c), representative of the actual weight of ore and the hot recycle setting, also are transmitted to a summator 48, which continuously determines their sum, as in the apparatus shown in Schuerger application Serial No. 579,326. This summator transmits a signal proportionate to said total to ratio devices 49, which regulate the speed of motors 25 driving the additive feeders 21, and to another ratio device 50, which regulates a valve 51 in the water line 27. These ratio devices are individually adjustable, whereby additives and water can be included in any desired ratio with respect to the sum of the ore and hot recycle. The Schuerger application cites specific examples of known instruments suitable as summators and ratio devices in this type of apparatus. These particular instruments operate on pneumatic pressure signals, but equivalent electrical instruments obviously could be substituted. If pneumatic instruments are used, the voltage signal from the hot recycle control mechanism can be converted into a proportionate pressure signal through a suitable transducer, such as that shown in a printed publication by the Foxboro Company, Foxboro, Massachuetts, Bulletin 20–16 entitled "E.M.F. Pneumatic Transmitter."

Feed rate computing circuit

FIGURE 2 shows the feed rate computing circuit 40 in more detail, apart from its timer circuit shown separately in FIGURE 3. Periodically the circuit 40 acts in conjunction with the burn-through indicator 39 to determine whether the burn-through point actually is at the location to which it has been set, and if not, to compute a new feed rate to shift burn-through point to the set location. If the burn-through point lies too far from the discharge end of the grate, the feed rate is increased; if it lies too near the discharge end, the feed rate is decreased. The circuit 40 exercises direct control only over the sum of the ore and hot recycle feed rate, but this sum is representative of the total feed rate, since the additives are proportioned directly in accordance therewith.

The burn-through indicator 39 includes a servomotor (designated 30 in the Dykeman and Schuerger application) which is mechanically connected to the arm 52 of a potentiometer 53. Thus the indicator 39 positions this arm along the potentiometer slide wire in accordance with the actual distance L between the ignition point and the burn-through point. A manually adjustable set-point indicator 54 is mechanically connected to the arm 55 of another potentiometer 56 to position this arm along the potentiometer slide wire in accordance with the set distance L_0 between the same ignition point and the burn-through point. The respective slide wires are connected to suitable D.-C. voltage sources, whereby arms 52 and 55 transmit voltages proportionate to L and L_0 respectively.

Arms 52 and 55 are electrically connected to a divider 57, which computes any variance between the actual and set locations of the burn-through point as a ratio L_0/L. The divider includes an electronic conversion amplifier 58, a servomotor 59 and a potentiometer 60 whose arm 61 is mechanically connected to the servomotor. Arm 55 is electrically connected to one input terminal of the amplifier, whereby the voltage applied to this terminal is proportionate to L_0. Arm 52 is electrically connected to one end of the slide wire of potentiometer 60, and arm 61 of the latter potentiometer is electrically connected to the other input terminal of the amplifier. Thus the voltage applied to the latter terminal is proportionate to L multiplied by a fraction whose value depends on the linear position of arm 61 with respect to its slide wire. Amplifier 58 and servomotor 59 are electrically connected to a suitable A.-C. source 62. The output terminals of amplifier 58 are electrically connected to a field winding 63 of the servomotor. Amplifier 58 has the characteristic that it energizes the servomotor in the appropriate direction whenever its two input terminals are at different voltages. When the servomotor runs, it moves arm 61 along its slide wire in a direction to equalize the voltages applied to the input terminals. When these voltages become equal, the servomotor stops and the linear position of arm 61 with respect to its slide wire affords a measurement of the ratio L_0/L. This computation can be made continuously, but it is used only periodically. We prefer not to operate the equipment unnecessarily; therefore we include front contacts A_1 of a relay A in series with the servomotor. The relay itself is part of the timer circuit hereinafter described, and it automatically closes these contacts whenever a computation is to be made.

The amplifier 58 per se is a known device and hence has been shown only in block form, but reference can be made to Wills Patent No. 2,423,540 for a complete showing of a suitable amplifier of this type. A suitable amplifier is available commercially from Minneapolis-Honeywell Regulator Company under the tradename "Electronik," No. 356,358, and is described in a printed publication by the manufacturer entitled "Service Manual 15019 M for Class 15 'Electronik' Instruments" Issue 8 (1956).

The servomotor 59 of the divider 57 also is mechanically connected to the arm 64 of a potentiometer 65. The slide wire of this potentiometer is connected to a D.-C. voltage source which applies a voltage proportionate to the instant feed rate F of material to grate 29, as hereinafter explained. Arm 64 assumes a position in accordance with the ratio L_0/L, whereby it transmits a voltage proportionate to the product FL_0/L. If there were no minor fluctuations to consider, the corrected feed rate F_0 would equal this product, since the corrected rate F_0 bears the same ratio to the actual rate F as the set distance L_0 between the ignition point and the burn-through point bears to the actual distance L, that is

$$\frac{F_0}{F}=\frac{L_0}{L}$$

However, we preferably apply the voltage transmitted by arm 64 to an integrator 66 for the purpose of computing an average value of FL_0/L over a definite time interval and thus eliminating effects of minor fluctuations or "noise" in the measured distance L.

The integrator includes an electronic conversion amplifier 67 (similar to amplifier 58), a servomotor 68, and a tachometer-generator 69 mechanically connected to the servomotor. The servomotor is a two-phase A.-C. induction motor which has the characteristic that under transient conditions its speed varies with the voltage applied to its field. We have not described the motor in detail since it is a known device, but for a complete description reference can be made to Thaler and Brown "Servo-Mechanisms Analysis," copyright 1953 by McGraw-Hill Book Company, Inc., pages 63 and 391. One input terminal of amplifier 67 is electrically connected to arm 64 of potentiometer 65, whereby the voltage applied to this terminal is proportionate to FL_0/L, but subject to fluctuations. The other input terminal of the amplifier is electrically connected to the generator 69, whereby the voltage applied to the latter terminal is proportionate to the output of the generator. The voltages applied to the two input terminals are of the same polarity, but the latter is smaller. Amplifier 67 and servomotor 68 are electrically connected to a suitable A.-C. source 70. The output terminals of amplifier 67 are electrically connected to a field winding 71 of servomotor 68. Front contacts A_2 of relay A are connected in series with servomotor 68, and are closed automatically by the timer circuit for a definite interval, for example one minute, when a computation is to be made. It should be pointed out that the integrator 66 is not a null-seeking device like the divider 57, but voltages applied to its two amplifier input terminals approach values which differ by an amount proportionate to the voltage to be integrated. The amplifier 67 allows the servomotor 68 to run as long as contacts A_2 remain closed.

The action of the integrator can be explained mathematically as follows:

Let

e_1 represent the input voltage to the amplifier proportionate to FL_0/L;

e_2 represent the input voltage to the amplifier derived from the tachometer-generator;

t represent the time interval the servomotor runs for each computation; and

x represents the number of revolutions of the tachometer-generator during time t.

Then

(e_2-e_1) is the effective voltage which tends to drive the servomotor; and

dx/dt is the angular velocity of the tachometer-generator.

$$e_2=K\frac{dx}{dt}$$

$$(e_2e_1)=K_1\frac{dx}{dt}$$

$$K=\frac{dx}{dt}-e_1=K_1\frac{dx}{dt}$$

$$e_1=(K-K_1)\frac{dx}{dt}$$

$$x=\frac{1}{K-K_1}\int e_1dt+\text{Constant}$$

Thus it is seen that x is a function of e_1, and measurement of x over a definite time interval can be used to obtain a measurement of an average value of e_1 or FL_0/L for the same interval.

The tachometer-generator 69 is mechanically connected to the arm 72 of a potentiometer 73 through suitable reduction gearing. Consequently the distance which the arm travels during time interval t furnishes a measure of the number of revolutions x during this interval. The slide wire of potentiometer 73 is electrically connected to a suitable D.-C. voltage source, whereby arm 72 transmits a voltage proportionate to the computed average value of FL_0/L during the interval t. This value is taken as F_0, the corrected feed rate.

After the computed value F_0 has been utilized, as hereinafter explained, the potentiometer arm 72 is reset to its zero position. For this purpose, the connection between arm 64 and the first input terminal of amplifier 67 contains a contact B_1 of a relay B and the connection between the generator 69 and the other input terminal of the amplifier contains a contact B_2 of relay B, which contacts are closed while the integrator is performing a computation. A contact B_3 of relay B is adapted to connect the first input terminal to a ground 74. A contact B_4 of relay B is adapted to connect the other input terminal to arm 72 of potentiometer 73. Additional contacts B_5 of relay B are adapted to connect servomotor 68 to the A.-C. source 70, bypassing contacts A_2. Contacts B_3, B_4 and B_5 are open while the integrator is performing a computation. Relay B itself is part of the timer circuit hereinafter described. When the potentiometer arm is to be reset, contacts B_1 and B_2 open and contacts B_3, B_4 and B_5 close. The servomotor 68 runs in the reverse direction until the voltages applied to the two input terminals of the amplifier 67 are equal. Since one terminal is grounded at 74, these voltages become equal when the other terminal is grounded, that is, when the potentiometer arm 72 reaches its zero setting. The integrator in effect becomes a null-seeking device while it is resetting the arm.

Before the arm 72 is reset, the voltage which it transmits proportionate to F_0 is applied to a memory device 75. The memory device includes an electronic conversion amplifier 76 (similar to amplifiers 58 and 67), a servomotor 77, and a potentiometer 78 whose arm 79 is mechanically connected to the servomotor. The slide wire of potentiometer 78 is electrically connected to a suitable D.-C. source. Arm 72 is electrically connected to one input terminal of amplifier 76, whereby the voltage applied to this terminal is proportionate to F_0. Arm 79 is electrically connected to the other input terminal of the amplifier, whereby the voltage applied to this terminal equals that applied to the slide wire of potentiometer 78 multiplied by a fraction whose value depends on the linear position of arm 79 with respect to the slide wire. Amplifier 76 and servomotor 77 are electrically connected to a suitable A.-C. source 80. The output terminals of amplifier 76 are electrically connected to a field winding 81 of the servomotor. The action of the memory device is similar to that of the divider 57; that is, the servomotor 77 stops after moving arm 79 to a linear position along its slide wire representative of the computed value of F_0. Front contacts C_1 of a relay C are connected in the A.-C. circuit 80. The relay itself is part of the timer circuit hereinafter described. Contacts C_1 automatically close long enough to enable the servomotor 77 of the memory device to set the potentiometer arm 79 to the new value of F_0 computed by the integrator. Thereafter these contacts reopen to hold the arm at this setting until another new setting is computed.

The servometer 77 of the memory device 75 also is mechanically connected to the arm 82 of a potentiometer 83, which is electrically connected to a suitable D.-C. source. Arm 82 thus assumes a position in accordance with the computed value of F_0, and transmits a proportionate voltage. Arm 82 is electrically connected to the trimmer bin control mechanism and transmits signal (a) thereto. As already explained the total feed rate bears a known ratio to the sum of the ore and hot recycle feed rates; hence the computed value of F_0 also is representative of this sum. The potentiometer arm 82 also is electrically connected to the slide wire of potentiometer 65 and transmits a voltage thereto to be used as F or the instant feed rate in the next computaion.

To shift the burn-through point intentionally, it is necessary only to move the set-point indicator to a new position of adjustment. Thereupon the circuit 40 computes a new feed rate which shifts the burn-through point to the new setting and holds it there after it has been shifted. If it is desired to operate the sintering machine at less than full capacity, it is only necessary to set the location of the burn-through point farther from the discharge end of the grate.

Manual adjustment

Preferably the feed rate computing circuit also includes means for adjusting the feed rate manually. A back contact D_1 of a relay D is connected between the potentiometer arm 72 and the memory device 75. A manually adjustable potentiometer 84 is connected to the memory device through a front contact D_2. Relay D itself is shown with the timer circuit. When manual control is to be employed, relay D is energized. Contact D_1 opens and disconnects the integrator 66 and preceding parts from the memory device 75. Contact D_2 closes and connects potentiometer 84 to the memory device, whereby the voltage applied to the memory device can be set manually through potentiometer 84. Circuit 80 to the servomotor 77 of the memory device contains front contacts D_3 which close when relay D is energized. The memory device transmits a signal for regulating the trimmer bin control mechanism 37 the same as when the automatic control means is connected.

Timer circuit

FIGURE 3 is a schematic wiring diagram of a preferred timer circuit. In addition to the relays A, B, C and D already mentioned, the circuit includes another relay E, two interval timers 90 and 91, and a switch 92 for setting the control to "manual" or "automatic." Timers 90 and 91 are of a type which have an adjustable "off-time" and an adjustable "on-time" that repeat as long as the timer is running. Such timers per se are known and are available commercially; hence no detailed showing is deemed necessary. However, reference can be made to a printed publication of General Electric Company entitled "TSA–18 Industrial Interval Timer" for a complete showing and description. The circuit is energized from two lines 93 and 94 connected to a suitable voltage source. Switch 92 and the coil of relay D are connected in series across lines 93 and 94. For automatic operation the switch is open and the relay deenergized, and for manual operation the reverse. Relay D has a back contact D_4 which connects the other relays and the timers to line 93 as long as relay D is deenergized, but breaks this connection when the relay is energized.

Timer 90 runs all the while the control is set for automatic operation. It has a contact 90*a* which opens during its "off-time" and closes during its "on-time." The "on-time" defines the interval t, hereinbefore referred to, during which a corrected feed rate F_0 is computed. Contact 90*a* and the coil of relay A are connected in series across lines 93 and 94, whereby the relay picks up during the "on-time" and drops out during the "off-time." When relay A picks up, its front contacts A_1 and A_2 close to operate servomotors 59 and 68 of the divider 57 and integrator 66 respectively, as already described. The coil of relay E, a front contact A_3 of relay A, and a back contact C_2 of relay C are connected in series across lines 93 and 94, whereby relay E picks up with relay A. Relay E has a front contact E_1 through which it seals in, by-passing contact A_3. The coil of relay B, a back contact E_2 of relay E, and a back contact C_3 of relay C are connected in series across lines 93 and 94, whereby relay B is normally energized, but drops out when relay E picks up. When relay B drops out, contacts B_1 and B_2 close to apply the voltages from arm 64 of potentiometer 65 and from the tachometer-generator 69 to the input terminals of the amplifier 67 of the integrator; contacts B_3 and B_4 open to break the connections to the ground 74 and to the arm 72 of potentiometer 73. Contacts B_5 open so that the servomotor 68 can be energized only via contacts A_2. Since relay B is normally energized, FIGURE 3 shows contacts B_1 and B_2 open even though they actually are back contacts, and contacts B_3, B_4 and B_5 closed even though they actually are front contacts.

Another front contact A_4 of relay A and timer 91 are connected in series across lines 93 and 94, whereby timer 91 is energized when relay A picks up. Timer 91 does not run continuously like timer 90, but is set to operate through only a single cycle of "off-time" and "on-time" whenever it is energized. Otherwise any synchronization errors in the timers would be cumulative, and soon would upset the sequence of operations. Timer 91 is also connected to line 93 through a conductor 95 and remains energized through this conductor after relay A drops out. The "on-time" of timer 90 ends an instant before the "on-time" of timer 91 commences. When the "on-time" of timer 90 ends, contact 90*a* opens, relay A drops out, and servomotors 59 and 68 stop. When the "on-time" of timer 91 commences, the timer closes a contact 91*a* which is connected in series with the coil of relay C across lines 93 and 94. Relay C picks up and closes its contacts C_1 to operate the servomotor 77 of the memory device 75. As long as relay D remains deenergized, the amplifier 76 of the memory device remains connected to arm 72 of potentiometer 73. The "on-time" of timer 91 is sufficient that the servomotor 77 operates long enough to set the memory device to the corrected feed rate F_0. Subsequently timer 91 is deenergized, whereupon contact 91*a* opens, and relay C drops out.

When relay C picks up, its back contacts C_2 and C_3 open. Opening of contact C_2 drops out relay E, but opening of contact C_3 for the moment prevents relay B from picking up. When relay C drops out, relay B picks up, whereupon its contacts B_3 and B_4 connect the amplifier 67 of the integrator to ground 74 and to the potentiometer arm 72, and its contacts B_5 energize the servomotor 68. Thus the potentiometer 73 is reset. It should be noted that relay B cannot be energized until both relays A and C are deenergized; consequently, the potentiometer 73 can be reset only when resetting does not interfere with other operations.

When our control is operated manually, switch 92 is closed and relay D picks up. Contacts D_1 and D_4 open, whereby the electrical connections are broken between the potentiometer arm 72 and amplifier 76 of the memory device 75 and between line 93 and the timer 90. Contact D_2 closes and establishes a connection between the manually operated potentiometer 84 and amplifier 76. Contacts D_3 close and establish a connection between the A.-C. circuit 80 and the servomotor 77 of the memory device. The way in which the memory device can be set manually with the contacts in these positions has already been explained.

Operating sequence

FIGURE 4 shows a typical sequence diagram for our feed rate control mechanism when set for automatic operation. Initially timer 90 is running but is registering "off-time," timer 91 is stopped, and relay B is energized. Thus no computation is taking place and relay B maintains the integrator 66 and potentiometer arm 72 in a reset or zero position. Presently the "on-time" of timer 90 commences. The timer circuit already described drops out relay B and starts timer 91, which at first registers "off-time." The divider 57 and integrator 66 now make their computation of a corrected feed rate, and potentiometer arm 72 is positioned accordingly. After an interval *t* the "on-time" of timer 90 ends and the timer goes back into "off-time." An instant later the "on-time" of timer 91 commences, but relay B remains deenergized. The potentiometer arm 72 remains positioned in accordance with this computed feed rate while the memory device 75 positions the potentiometer arm 82 accordingly. Signal (a) and the ore feed rate are corrected simultaneously with the positioning of arm 82. Subsequently the "on-time" of timer 91 ends and this timer stops. Relay B picks up to reset the potentiometer arm 72, but the potentiometer arm 82 retains its setting until a new computation is made.

The interval between computations should approximate the time required for a particle to travel from the trimmer bins 16 to the discharge end of grate 29, typically about 45 minutes. The duration of a computation should be sufficient to furnish a representative average of conditions prevalent on the grate, typically about 1 to 2 minutes. The interval for setting the memory device should be long enough only for the parts to reach their computed positions, allowing a reasonable margin, typically about 15 to 30 seconds. Thus timer 90 can be set for about 45 minutes "off-time" and about 1 to 2 minutes "on-time," and timer 91 for "off-time" an instant longer than the "on-time" of timer 90 and about 15 to 30 seconds "on-time."

Grate speed control mechanism

FIGURE 5 shows the grate speed control mechanism 33 in more detail. This mechanism comprises a speed computing circuit 98 and a motor control 99. Whenever the bed depth is outside the desired range, the speed computing circuit 98 computes a new grate speed which equals the algebraic sum of the instant speed, a temporary increment (positive or negative) to return the depth to the desired range, and a permanent increment (positive or negative) to hold it in the desired range after it has returned. Both increments are of course negative when the bed is too shallow and positive when it is too deep. After the increments are applied to the motor speed and the bed depth returns to the desired range, the circuit 98 computes another new speed which equals the instant speed with the temporary increment discontinued. The speed computing circuit 98 acts periodically, but its cycle is short (for example 5 seconds computing and 5 seconds between computations), whereby the mechanism effectually exercises continuous control over the grate speed.

The speed computing circuit 98 is energized through lines 100 and 101 connected to a suitable D.-C. source. The low level sensing means 34 controls a contact 34*a* which is connected across these lines in series with the coil of a relay H. The high level sensing means 35 controls a contact 35*a* which is connected across these lines in series with the coil of a relay J. Whenever the bed S becomes too shallow to actuate either sensing means 34 or 35, both contacts 34*a* and 35*a* open and both relays H and J are deenergized. When the bed depth is within the desired range and actuating the low level sensing means 34, contact 34*a* closes and relay H picks up. Whenever the bed becomes so deep that it actuates both sensing means 34 and 35, both contacts 34*a* and 35*a* close and both relays H and J pick up.

Relays H and J control a pair of relays K and L, which in turn control the application of negative and positive temporary speed change increments respectively. The coil of relay K is connected across lines 100 and 101 in series with a back contact H_1 of relay H and a front contact T_1 controlled by a timer T. Similarly the coil of relay L is connected across these lines in series with a front contact J_1 of relay J and a front contact T_2 of the timer. Timer T automatically and periodically opens and closes its contacts for brief intervals. If the bed depth is within the desired range when the timer closes its contacts T_1 and T_2, neither relay K nor L picks up, since both contacts H_1 and J_1 remain open. If the bed is too shallow, relay K picks up with the closing of timer contact T_1, since relay H is deenergized and its contact H_1 closed. Similarly if the bed is too deep, relay L picks up with the closing of timer contact T_2, since relay J is energized and its contact J_1 closed. Whenever either relay K or L picks up, it seals in via back contact T_3 or T_4 of the timer and its own front contact K_1 or L_1. Relays K and L are relatively slow-acting to enable them to remain energized during the interval contacts T_1 and T_2 are opening and contacts T_3 and T_4 closing. After a temporary increment in the speed returns the bed depth to the desired range, contact H_1 or J_1 immediately opens. The next time timer T opens its contacts T_3 and T_4, relay K or L drops out and the temporary increment is discontinued.

Relays H and J also control a reversing motor 102 which in turn controls the application of permanent speed change increments. This motor is connected across lines 100 and 101 in series with back contacts H_2 and H_3 of relay H and front contacts T_5 and T_6 of timer T for energizing it in one direction, and in series with front contacts J_2 and J_3 of relay J and the same contacts T_5 and T_6 for energizing it in the opposite direction. If the bed depth is within the desired range when timer T closes its contacts T_5 and T_6, the motor does not operate, since contacts H_2, H_3, J_2 and J_3 are all open. If the bed is too shallow, the motor runs in a direction to apply a negative increment, since relay H is deenergized and contacts H_2 and H_3 are closed. Similarly if the bed is too deep, the motor runs in the opposite direction to apply a positive increment, since relay J is energized and contacts J_2 and J_3 are closed. In either event the motor stops when timer T opens its contacts T_5 and T_6, thus limiting the magnitude of the permanent increment.

The circuit includes a potentiometer 103 whose slide wire is connected to a suitable D.-C. source for developing a speed controlling voltage. The potentiometer has an arm 104 which is electrically connected to an output terminal 105 via two variable resistances 106 and 107 in series, and is mechanically connected to motor 102. A back contact K_2 of relay K is connected in parallel with resistance 106 and thus normally shunts out this resistance. When relay K picks up as a result of a shallow bed, contact K_2 opens and places resistance 106 in series with arm 104 and terminal 105. Consequently the voltage transmitted to the terminal drops to effect a negative temporary speed increment. A front contact L_2 is connected in parallel with resistance 107. When relay L picks up as a result of an excessively deep bed, contact L_2 closes and shunts out the latter resistance. Consequently the voltage transmitted to the terminal rises to effect a positive temporary speed increment. The magnitude of temporary increments can be adjusted by adjusting resistances 106 and 107. When motor 102 runs, it moves arm 104 along the slide wire in a direction to lower or raise the voltage transmitted to the terminal to effect a negative or a positive permanent speed increment. The magnitude of permanent increments can be adjusted by adjusting the length of time the motor runs. The ultimate voltage on the output terminal 105 is proportionate to the most recently computed speed for motor 31 and is transmitted to the motor control 99.

The motor control 99 illustrated includes a motor-generator 108 and a magnetic amplifier 109 which has a control winding 110. The magnetic amplifier and motor portion of the motor-generator are connected to suitable A.-C. sources. Terminal 105 of the speed computing circuit is electrically connected to the winding 110 and continuously transmits thereto a voltage proportionate to the most recently computed speed for motor 31. The magnetic amplifier is connected to a field winding 112 of the D.-C. generator, whereby the voltage applied to the field winding, and hence the voltage output of the generator, vary with the voltage applied to the control winding 110. The generator is electrically connected to the D.-C. motor 31, whose speed thus is governed by this same voltage. We have not described the magnetic amplifier in detail since it is a known device, but for a complete description reference can be made to Storm "Magnetic Amplifiers," Copyright 1955 by General Electric Company. An explanation of the way a magnetic amplifier can be used as a voltage regulator for a D.-C. generator appears on pages 418 and 419 of this publication.

From the foregoing description it is seen that our invention affords a fully automatic mechanism and method for controlling a sintering operation. Except for setting the desired proportions of additives and water in the sinter mix, the only adjustment necessary is in setting the location at which it is desired to maintain the burn-through point. The mechanism then automatically controls the feed rate and grate speed to hold the burn-through point at this location. Similar results can be attained by using the individual control devices shown in our other applications, except that it is necessary also to use a surge bin between the compounding apparatus and the sintering machine. The present invention overcomes any need for a surge bin, since the feed rate to the compounding apparatus is controlled directly to produce the actual feed needed in the sintering machine.

While we have shown and described only a single embodiment of the invention, it is apparent that other modifications may arise. Therefore, we do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

We claim:

1. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising computing means operatively connected with said indicator for computing feed rates to hold the burn-through point at a set location on the grate, and means operatively connected with said computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates.

2. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising computing means operatively connected with said indicator for computing feed rates to hold the burn-through point of the bed at a set location on the grate, means operatively connected with said computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates, and means operatively connected with said machine to regulate the speed at which its grate travels to maintain the depth of the bed within a predetermined range.

3. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients to form a combustible sinter mix and feeding the mix to said machine, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising a set-point indicator, computing means operatively connected with said indicators for periodically computing

a new feed rate to shift the burn-through point from its actual location on the grate indicated by said burn-through indicator to a set location indicated by said set-point indicator, means operatively connected with said computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates, and timing means operatively connected with said computing means for regulating the period between successive operations thereof to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

4. A combination as defined in claim 3 in which said computing means includes means for averaging the computation of a new feed rate over a sufficient period to eliminate effects of minor fluctuations.

5. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising a set-point indicator, computing means operatively connected with said indicators for periodically computing a new feed rate to shift the burn-through point of the bed from its actual location on the grate indicated by said burn-through indicator to a set location indicated by said set-point indicator, means operatively connected with said computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates, timing means operatively connected with said computing means for regulating the period between successive operations thereof to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate, and means operatively connected with said machine to regulate the speed at which its grate travels to maintain the depth of the bed within a predetermined range.

6. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising a set-point indicator, a first computing means operatively connected with said indicators for determining as a ratio any discrepancy between the actual location of the burn-through point on the grate indicated by said burn-through indicator and the set location indicated by said set-point indicator, a second computing means operatively connected with said first computing means for periodically computing as an average over a period sufficient to eliminate effects of minor fluctuations a new feed rate to shift the burn-through point from its actual location to its set location, means operatively connected with said second computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates, and timing means operatively connected with said second computing means for regulating the period between successive operations thereof to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

7. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine, the combination therewith of a control mechanism comprising a set-point indicator, a first computing means operatively connected with said indicators for determining as a ratio any discrepancy between the actual location on the grate of the burn-through point of the bed indicated by said burn-through indicator and the set location indicated by said set-point indicator, a second computing means operatively connected with said first computing means for periodically computing as an average over a period sufficient to eliminate effects of minor fluctuations a new feed rate to shift the burn-through point from its actual location to its set location, means operatively connected with said second computing means and said apparatus for regulating the quantity of sinter mix fed to said machine in accordance with computed rates, timing means operatively connected with said second computing means for regulating the period between successive operations thereof to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate, and means operatively connected with said machine to regulate the speed at which its grate travels to maintain the depth of the bed within a predetermined range.

8. In a sintering installation which includes a traveling grate sintering machine, a compounding apparatus for assembling ore, additives and hot recycle, means operatively connected with said apparatus for proportioning the rate at which additives are included in accordance with the sum of the ore and hot recycle rates, and means for mixing materials assembled in said apparatus and feeding them to said machine, the combination therewith of a control mechanism comprising computing means operatively connected with said machine for computing feed rates required to hold the burn-through point at a set location on the grate, and means operatively connected with said computing means and said apparatus for adjusting the sum of the ore and hot recycle rates in accordance with the computed feed rate.

9. In a sintering installation which includes a traveling grate sintering machine, a compounding apparatus for assembling ore, additives and hot recycle, means operatively connected with said apparatus for proportioning the rate at which additives are included in accordance with the sum of the ore and hot recycle rates, and means for mixing materials assembled in said apparatus and feeding them to said machine to form a bed on the grate thereof, the combination therewith of a control mechanism comprising computing means operatively connected with said machine for computing feed rates required to hold the burn-through point of the bed at a set location on the grate, means operatively connected with said computing means and said apparatus for adjusting the sum of the ore and hot recycle rates in accordance with the computed feed rate, and means operatively connected with said machine to regulate the speed at which its grate travels to maintain the depth of the bed within a predetermined range.

10. In a sintering installation which includes a traveling grate sintering machine, a compounding apparatus for assembling ore, additives and hot recycle, means operatively connected with said apparatus for regulating the rate at which hot recycle is included at substantially the rate received, means operatively connected with said apparatus for proportioning the rate at which additives are included in accordance with the sum of the ore and hot recycle rates, and means for mixing materials assembled in said apparatus and feeding them to said machine, the combination therewith of a control mechanism comprising computing means operatively connected with said machine for computing feed rates required to hold the burn-through point at a set location on the grate, and means operatively connected with said computing means and said apparatus for adjusting the ore rate to values at which the sum of the ore and hot recycle rates is in accordance with the computed feed rate.

11. In a sintering installation which includes a traveling grate sintering machine, a compounding apparatus for assembling ore, additives and hot recycle, means operatively connected with said apparatus for proportioning the rate at which additives are included in accordance with the sum of the ore and hot recycle rates, means for mixing materials assembled in said apparatus and feeding them to said machine, and a burn-through indicator operatively connected with said machine, the combina-

tion therewith of a control mechanism comprising a set-point indicator, computing means operatively connected with said indicators for periodically computing a new feed rate to shift the burn-through point from its actual location on the grate indicated by said burn-through indicator to a set location indicated by said set-point indicator, means operatively connected with said computing means and said apparatus for adjusting the sum of the ore and hot recycle rates in accordance with the computed feed rate, and timing means operatively connected with said computing means for regulating the period between successive operations thereof to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

12. A method of controlling a traveling grate sintering operation comprising periodically computing rates of feeding material to the grate to shift the burn-through point from its actual location to a set location, changing the feed rate to the computed rate, and regulating the speed at which the grate travels to maintain the depth of material thereon within a predetermined range.

13. In a sintering operation wherein ore, additives and hot recycle are brought together, mixed and fed to a traveling grate sintering machine to form a bed on the grate thereof, a method of control comprising periodically computing a new feed rate to shift the burn-through point of the bed from its actual location on the grate to a set location, changing the sum of the ore and hot recycle rates in accordance with the computed new rate, proportioning additives in accordance with this sum, the period between successive computing steps approximating the time taken for material of a new feed rate to reach the discharge end of the grate and regulating the speed at which the grate travels to maintain the depth of the bed within a predetermined range.

14. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine for indicating the actual location of the burn-through point on the grate, the combination therewith of a control mechanism comprising a set point indicator for indicating the desired location of the burn-through point, respective voltage sources operatively connected with said indicators for developing a first voltage which varies with the actual location of the burn-through point and a second voltage which varies with the desired location, a divider operatively connected with said voltage sources for determining the ratio of said voltages and thus determining the magnitude of any discrepancy between the actual and desired locations, means for developing a third voltage proportionate to the instant feed rate of sinter mix to said sintering machine, multiplying means operatively connected with said last named means and said divider for developing a fourth voltage proportionate to the product of said third voltage and said ratio and thus determining a corrected feed rate to shift the burn-through point to the desired location, means operatively connected with said multiplying means and said apparatus for periodically changing the feed rate to the corrected value, and timing means for regulating the period between successive corrections in the feed rate to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

15. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine for indicating the actual location of the burn-through point on the grate, the combination therewith of a control mechanism comprising a set point indicator for indicating the desired location of the burn-through point, respective voltage sources operatively connected with said indicators for developing a first voltage which varies with the actual location of the burn-through point and a second voltage which varies with the desired location, a divider operatively connected with said voltage sources for determining the ratio of said voltages and thus determining the magnitude of any discrepancy between the actual and desired locations, means for developing a third voltage proportionate to the instant feed rate of sinter mix to said sintering machine, multiplying means operatively connected with said last named means and said divider for developing a fourth voltage proportionate to the product of said third voltage and said ratio and thus determining a corrected feed rate to shift the burn-through point to the desired location, averaging means operatively connected with said multiplying means for developing periodically a fifth voltage proportionate to said fourth voltage averaged over an interval sufficient to eliminate effects of minor fluctuations in the actual location, a memory device operatively connected with said averaging means and said apparatus for periodically changing and holding the feed rate at the corrected value until another corrected value is determined, and timing means operatively connected with said averaging means and said memory device for regulating the period between successive corrections in the feed rate to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

16. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine for indicating the actual location of the burn-through point on the grate, the combination therewith of a control mechanism comprising a set point indicator for indicating the desired location of the burn-through point, respective voltage sources operatively connected with said indicators for developing a first voltage which varies with the actual location of the burn-through point and a second voltage which varies with the desired location, a divider operatively connected with said voltage sources for determining the ratio of said voltages and thus determining the magnitude of any discrepancy between the actual and desired locations, means for developing a third voltage proportionate to the instant feed rate of sinter mix to said sintering machine, multiplying means operatively connected with said last named means and said divider for developing a fourth voltage proportionate to the product of said third voltage and said ratio and thus determining a corrected feed rate to shift the burn-through point to the desired location, an integrator operatively connected with said multiplying means for developing periodically a fifth voltage proportionate to said fourth voltage averaged over an interval sufficient to eliminate effects of minor fluctuations in the actual location, a memory device operatively connected with said integrator and said apparatus for periodically changing and holding the feed rate at the corrected value until another corrected value has been determined, the means for developing said third voltage being operatively connected with said memory device, and timing means operatively connected with said integrator and said memory device for regulating the period between successive corrections in the feed rate to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

17. In a sintering installation which includes a traveling grate sintering machine, apparatus for assembling and mixing ingredients of a combustible sinter mix and feeding the mix to said machine to form a bed on the grate thereof, and a burn-through indicator operatively connected with said machine for indicating the actual location of the burn-through point on the grate, the combina-

tion therewith of a control mechanism comprising a set point indicator for indicating the desired location of the burn-through point, respective voltage sources operatively connected with said indicators for developing a first voltage which varies with the actual location of the burn-through point and a second voltage which varies with the desired location, a divider operatively connected with said voltage sources for determining the ratio of said voltages and thus determining the magnitude of any discrepancy between the actual and desired locations, means for developing a third voltage proportionate to the instant feed rate of sinter mix to said sintering machine, multiplying means operatively connected with said last named means and said divider for developing a fourth voltage proportionate to the product of said third voltage and said ratio and thus determining a corrected feed rate to shift the burn-through point to the desired location, an integrator operatively connected with said multiplying means for developing periodically a fifth voltage proportionate to said fourth voltage averaged over an interval sufficient to eliminate effects of minor fluctuations in the actual location, a memory device operatively connected with said integrator and said apparatus for periodically changing and holding the feed rate at the corrected value until another corrected value has been determined, the means for developing said third voltage being operatively connected with said memory device, means operatively connected with said sintering machine for regulating the speed at which the grate travels to maintain the bed depth within a predetermined range despite variations in the feed rate, and timing means operatively connected with said integrator and said memory device for regulating the period between successive corrections in the feed rate to approximately the time taken for mix of corrected feed rate to reach the discharge end of the grate.

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