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RATIO CONTROL OF BINDER TO CONCENTRATE

Filed Dec. 9, 1957

5 Sheets-Sheet 1

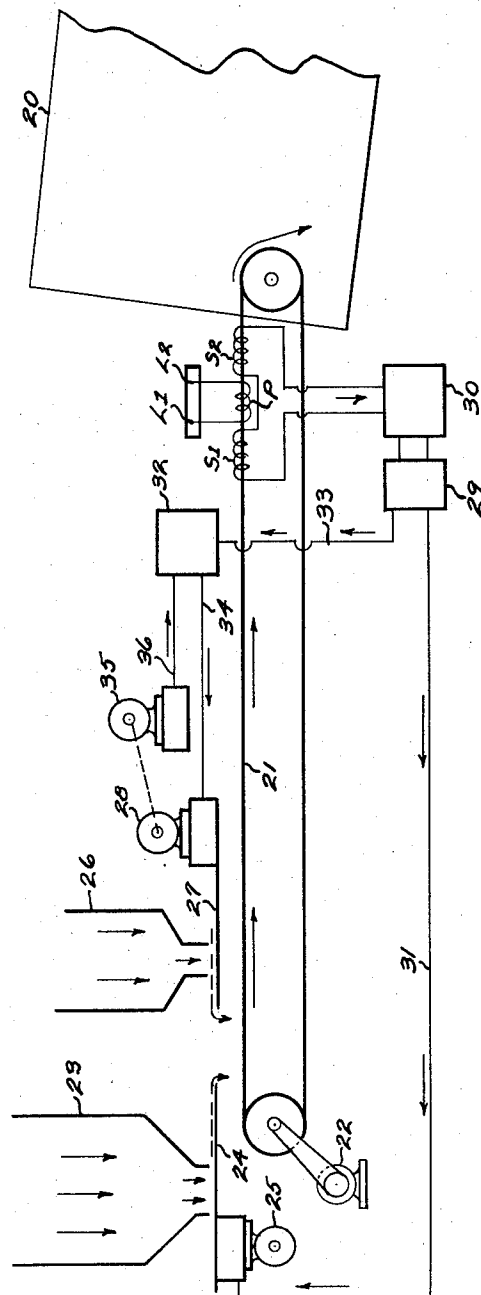


FIG. 1

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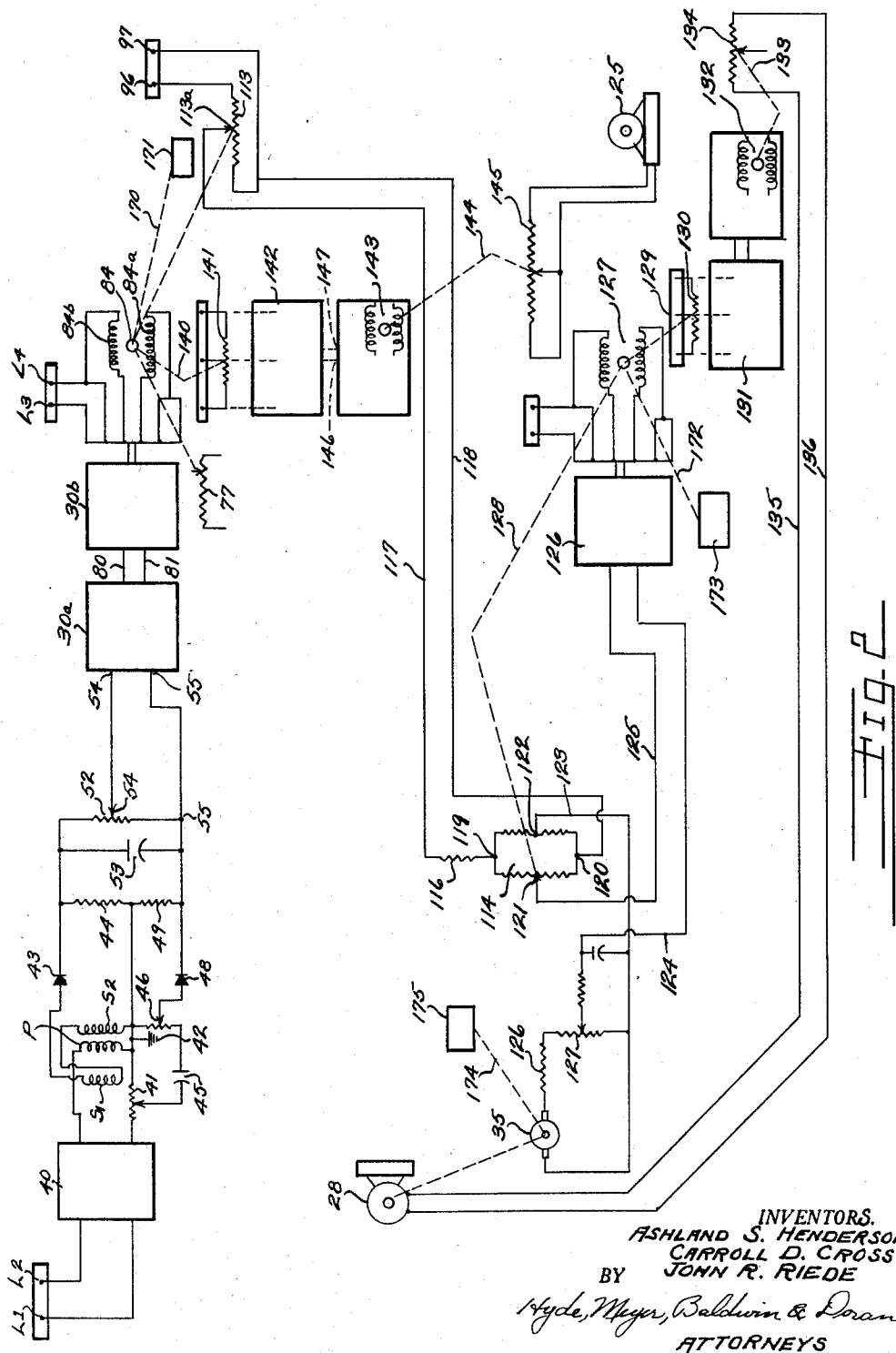
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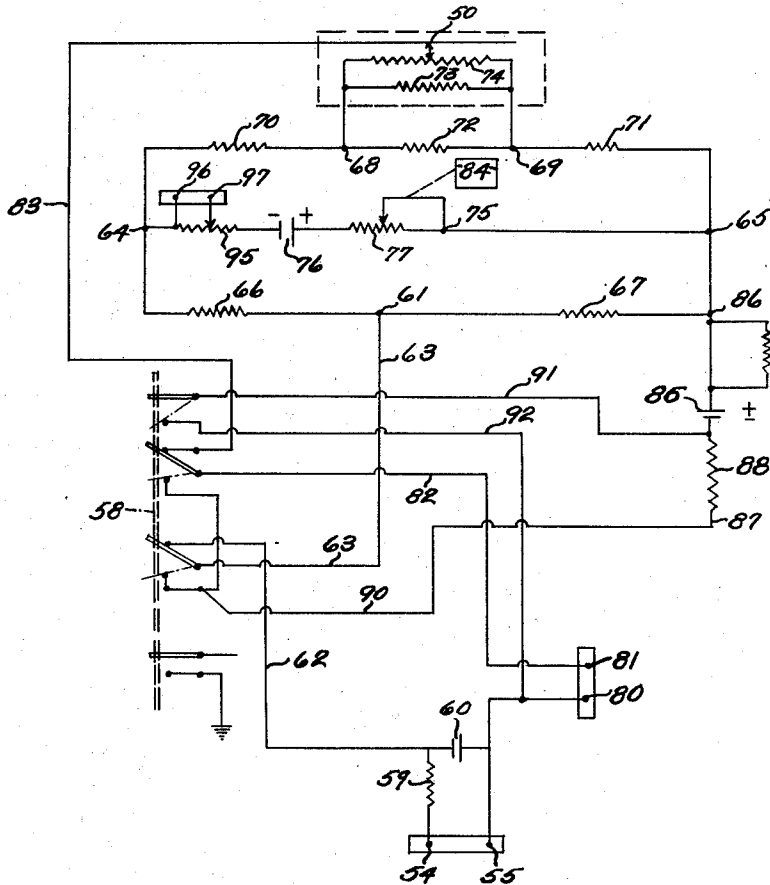


Fig. 3

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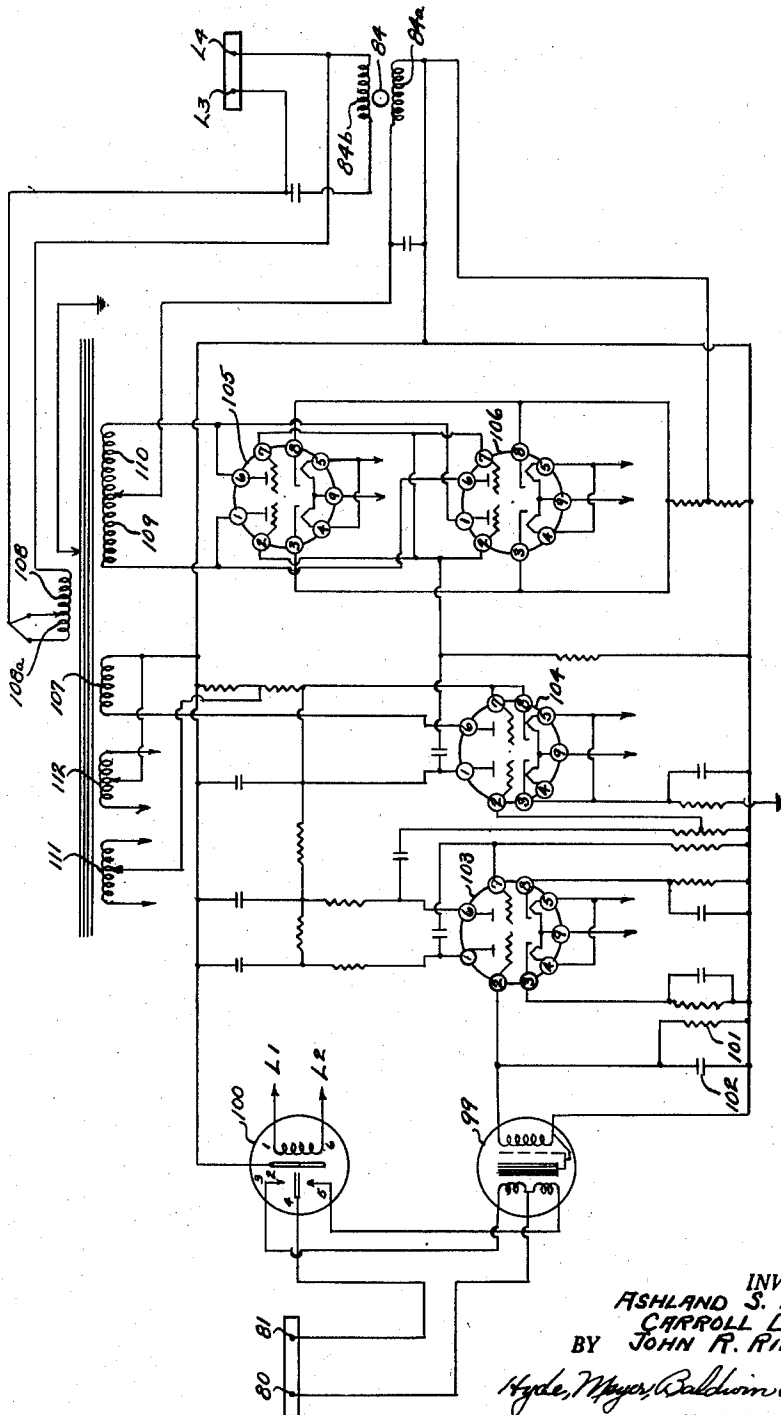
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5 Sheets-Sheet 4



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RATIO CONTROL OF BINDER TO CONCENTRATE

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5 Sheets-Sheet 5

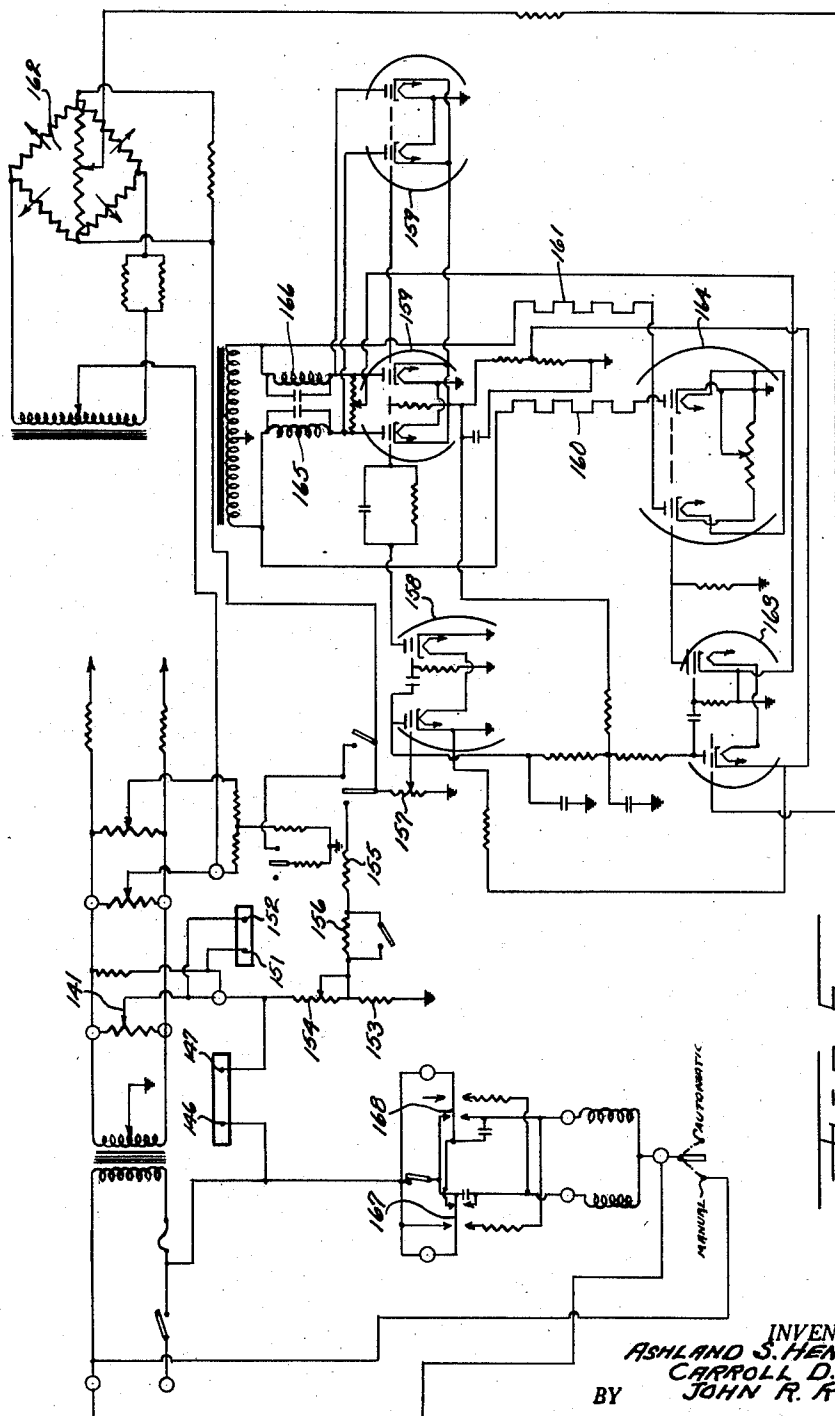


FIG. 5

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RATIO CONTROL OF BINDER TO CONCENTRATE

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Application December 9, 1957, Serial No. 701,673

11 Claims. (Cl. 222—57)

This invention relates to novel and improved methods and means for automatically controlling the amount of a binder material to be added to a base material which has magnetic characteristics. It is particularly adapted to the automatic control of the amount of a binder material to be added to a comminuted mass of ore having a substantial proportion of magnetic oxide of iron therein. As a convenient example of one advantageous adaptation of the invention it will be described in connection with the operation of pelletizing beneficiated taconite concentrate.

In the final step of preparing balls, compacts or pellets of such concentrate they are indurated by heating and burning, in a continuous process, such as in a moving grate furnace or a stack furnace. During the formation of the pellets prior to induration it has been found advisable to add a small proportion of a binder material, such as bentonite or starch, to the concentrate powder so as to promote adhesion of the particles while they are being formed into pellets, and further maintain the shape of these pellets during the step of conveying them to and through the induration furnace. The powdered concentrate, mixed with the desired amount of binder, is fed to a large hollow drum which is rotating on a slightly inclined axis, with the moist concentrate powder turning over and over on the inner drum wall while simultaneously progressing towards the discharge end of the drum. The ore particles agglomerate by "snowballing" into spherical particles ranging in size from one quarter inch to somewhat over one inch in diameter, or possibly larger. By suitable control of the moisture, the speed of rotation of the drum, the percentage of binder material, and other factors, the production of spherical or approximately spherical balls or compacts may be satisfactorily accomplished. When properly made the pellets are strong enough to hold their shape preparatory to the heat hardening or induration step.

From what has been said it will be apparent that the feed of concentrate and binding material must be controlled so as to produce green pellets of proper adhesive characteristics. If too much binder is needed it is economically undesirable by reason of the cost of the binder, and it reduces to a minor extent the iron content of the pellets. If insufficient binder is used, then breakage of pellets increases in the subsequent handling, besides which the pellets do not form as readily in the balling drum.

The primary object of the invention is to control the amount of magnetic iron concentrate fed to the balling drum independent of its feeding characteristics, while simultaneously adding to the concentrate powder a predetermined weight of binder to the concentrate so as to achieve the proper ratio of the two ingredients.

A further object of the invention is to maintain constant the concentrate-binder ratio regardless of variations in concentrate quantity.

A further object of the invention is to provide a uniform control circuit which will correct for any changes in feeding characteristics of either ingredient.

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Other objects and advantages will be apparent from a study of the following description of one mode of practicing the invention, in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic showing, of flow-diagram type, showing the main elements of the invention.

Fig. 2 is an electrical wiring diagram showing the operative relationship of the various electrical elements of the system.

Figs. 3, 4 and 5 are more detailed circuit diagrams of particular control elements of the system.

Referring first to Fig. 1 for a general understanding of our invention the pellets are formed in a balling drum 20 fed by a continuous conveyor 21 which may be a slightly concaved or shallow trough belt. Belt 21 travels in the direction of the arrows, being driven at a pre-selected constant speed by motor 22. Concentrate powder, consisting in the present instance of beneficiated taconite ore having a high magnetic content, is discharged from a source such as bin 23 onto a variable speed table feeder 24 from which it discharges to conveyor 21. Table feeder 24 is energized by a variable speed motor 25. It will be understood that by suitable control of the current to motor 25 it is possible to control the amount of concentrate delivered to conveyor 21 by table feeder 24.

A suitable binder material, in finely ground form, is fed from a bin 26 to a table feeder 27, and discharged therefrom to conveyor 21 so as to travel with the concentrate to drum 20. Table feeder 27 is operated by a motor 28. Here again it is apparent that by varying the electrical input to motor 28 it is possible to vary the amount of binder delivered to conveyor 21.

Control of motors 25 and 28 will be briefly discussed here, and later will be described in detail in connection with the more detailed wiring diagrams, Figs. 2 to 5.

Conveyor 21 carrying the concentrate and binder passes in succession through three annular coils constituting an inductive couple consisting of a primary coil P disposed between a pair of appropriately connected secondary coils S₁ and S₂. The primary is energized by any suitable source of alternating or pulsating current applied at terminals L₁—L₂. Variations in the amount of magnetic material passing axially through the primary coil produces corresponding and proportional variations in an alternating current induced in the secondary coils S₁ and S₂. These secondary variations are imposed on a controller 29 through an amplifier 30. One function of the controller is to regulate the speed of motor 25 through a circuit 31 to deliver a uniform amount of magnetic concentrate to conveyor 21. Another function of controller 29 is to send a signal to a second controller 32 through a circuit 33. This second controller 32 through a circuit 34 controls the operation of motor 28, to maintain the ratio of binder to concentrate in a predetermined proportion.

In addition to their functions in the control operation just described, controllers 29 and 32 may be provided with indicating means to respectively show, in actual weight units, the amount of concentrate and binder being delivered to the balling drum. The amount of magnetic material sensed by the primary-secondary inductive couple is also a measure of the total weight of concentrate because the concentrate composition is quite uniform, and a measure of its magnetic content gives a reliable indication of its total weight. The indicating means which is a part of controller 29 can therefore be calibrated in tons of concentrate per unit of time.

The indicating means associated with controller 32 can register the amount of binder delivered by table feeder 27, in the following manner. Motor 28 operates a tachometer generator 35 which of course varies its elec-

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trical output proportionally to variation in speed of motor 28. This electrical output, through a circuit 36, feeds back a signal to controller 32, which signal is therefore proportional to the amount of binder delivered by table feeder 27. This feed-back signal is supplied to an indicator in controller 32. The indicator not only can be calibrated to read in pounds of binder per unit of time, but it can be integrated with a signal from the concentrate controller 29 to show the simultaneous exact ratio of concentrate to binder.

As a brief résumé, the inductive couple is sensitive to variations in the amount of magnetic material in the conveyor burden. A first controller, in response to a varying signal from the inductive couple, transmits a proportionally varying current to the motor which controls the delivery of concentrate so as to maintain the delivery as constant as is practicable. Simultaneously this first controller transmits a signal to a second controller which regulates the binder feed. The binder feed sends back to the second controller a signal which can be integrated with the signal from the first controller to show, at any instant, the exact ratio of concentrate to binder. Indicator means are provided to show the actual weight of concentrate and binder.

Referring now to the electrical circuits and members associated therewith we show, in the upper left portion of Fig. 2, the sensing means for quantitatively determining the amount of magnetic concentrate moving in a path past the induction couple consisting of primary coil P, and two secondary coils S_1 and S_2 which in a structural assembly are axially spaced one on each side of the primary. The conveyor 21 (Fig. 1) passes axially through the couple, and any magnetic material thereon increases the induced current in S_1 , S_2 . An A.C. current from L_1 , L_2 feeds into a constant voltage transformer 40 through a resistor 41 into primary P. One side is grounded at 42. The voltage developed in S_1 , S_2 is proportional to the quantity of magnetic concentrate on the conveyor.

The A.C. current flowing in the secondary circuit is rectified by diode 43 so that the D.C. voltage drop across resistor 44 is proportional to the aforesaid amounts of magnetic material. It is necessary to make an operating correction for extraneous effects in the operating circuit other than those resulting from passage of the magnetic concentrate on the conveyor. This correction is effected by taking part of the transformer output through a phasing capacitance 45 and a variable resistor 46. In essence, the object is to vary resistor 46 to produce at diode rectifier 48 a voltage equivalent to that at diode 43 when the circuits are energized but no magnetic material is passing on the conveyor. Under these conditions the D.C. voltage across resistor 44 is equal and opposite to the D.C. balancing voltage across resistor 49 with no magnetic material passing:

A variable resistor 52 and a coupled capacitor 53 act as a matched resistance-capacitance circuit to dampen the signal developed by passage of magnetic material. Resistor 52 could be of fixed value, but for convenience a variable resistor is provided to modify the signal voltage at points 54, 55, so that a signal of predetermined potential can be fed to the subsequent circuit elements.

The signal from points 54, 55 is shown in Fig. 2 as being delivered in succession to two units, in this drawing identified by reference numerals 30a and 30b and consisting respectively of a measuring circuit and an amplifier, these items being incorporated in the block marked 30 in Fig. 1. The measuring circuit is shown in greater detail in Fig. 3 and a suitable amplifier in Fig. 4.

Referring now to Fig. 3, the points 54 and 55 on Fig. 2 may be indicated as the input points similarly identified at the bottom of Fig. 3. In the circuit of Fig. 3, as will directly appear we have provided a battery-balanced resistance bridge. The battery is periodically checked against a commercially obtainable laboratory standard

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cell which, when used only as an occasional check means, remains at constant value for a long period. We have provided a multiple throw switch 58 which can be manually thrown to a check position at selected intervals, but which normally is in the opposite or running position.

At the signal input point there is a resistor-capacitor alternating circuit consisting of resistor 59 and a capacitor 60. Switch 58 is in the upper or normal operating position, which places resistor 59 in electric circuit communication with point 61 through lines 62 and 63. The upper part of Fig. 3 constitutes a balancing bridge of the Wheatstone general type, in which points 64, 61, 65, and the intermediate resistors 66 and 67 form a lower arm, and points 64, 68, 69, and 65, and the intermediate resistors 70, 71, and the parallel resistor assembly 72, 73 and 74 form the upper arm. The intermediate cross arm 64, 75, 65 contains the battery 76 and a variable resistor 77. In the parallel resistor bank 72, 73, 74, is a variable element 50 for balancing purposes.

Battery 76 supplies a constant voltage between points 64 and 65. This voltage is arranged to be of opposite polarity to the signal being measured. With the switch still in the upper position the incoming signal to be measured proceeds from point 54 through lines 62 and 63 to point 61, and from point 55 through the amplifier (connected at points 80 and 81) and then through lines 82 and 83 to point 50. Signal voltage at the terminal points 61 and 50 therefore is disposed, by means of the measuring bridge above described, to be opposed in polarity to the voltage of battery 76. The amplifier (Fig. 4) in series with terminals 80 and 81 is connected to measure and amplify any difference between the established battery voltage and the fluctuations in the incoming signal at 54, 55, coming from the induction couple heretofore described. The amplified current energizes a motor 84 (Fig. 2) which in turn operates several items, as will appear. It may now be stated that one of its functions is to operate the sliding contact on resistor 74 (Fig. 3) to a position such that the voltage produced by battery 76 across points 61 and 81 is equal and opposite to the incoming signal at 54, 55. It is apparent that when the signal is thus balanced there will be no output signal at points 80 and 81, which will in turn leave no potential to be amplified and consequently motor 84 (Fig. 2) will stop. Motion of the motor to the stop position, however, will have made the necessary adjustments in the further controlled elements to achieve the results desired.

To assure a proper balancing voltage output from battery 76 (Fig. 3) it is occasionally checked against a standard cell 85, as follows. Manual switch 58 is moved to its checking position, during which movement a clutch mechanism (not shown) simultaneously connects the slider on resistor 77 with motor 84 (Fig. 2).

With the switch in the down or "check" position the voltage originating in battery 76 and developed across resistor 67 is compared with the voltage of standard cell 85 and impressed between points 86 and 87. Since the signal voltage at terminals 54 and 55 has been disconnected by moving switch 68 to the check position, the amplifier will now amplify a differential impressed across resistor 88, the amplifier circuit proceeding from terminal 81 through lines 82, 90, resistor 88, and lines 91 and 92 to terminal 80. Any detectable potential difference between the battery 76 and standard cell 85 will be amplified by the amplifier which will cause motor 84 to move and to operate the sliding contact on variable resistor 77 so as to cause the battery voltage across resistor 67 to balance the standard cell voltage by making the two voltages equal and opposite. This will periodically check and adjust the battery voltage and insure accurate measuring of the incoming signal at 54, 55. Switch 58 is of course returned to the upper or normal operating position after each check.

In this measuring circuit, Fig. 3, no reference has as yet been made to resistor 95. This resistor, by means of

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the fixed terminal point 96 and the movable terminal point 97 will be later referred to. Briefly this variable resistor provides a potential drop arrangement which is used as a supply of constant voltage, low wattage power for a retransmitting slidewire unit.

Proceeding from terminal points 80 and 81 of Fig. 3 we arrive at the similarly identified terminal points at the left side of the amplifier diagram, Fig. 4. This shows a fairly conventional D.C. amplifier which takes the low potential signal coming in at 80, 81 and amplifies it sufficiently to energize balancing motor 84 (Fig. 2). As has been seen, the balancing motor operates to return the energizing voltage to a zero value. As heretofore intimated, as long as the voltage at terminals 54, 55 (Fig. 3) is constant no potential difference is detected at terminals 80, 81. The position to which motor 84 moves to achieve this balance is then representative of the signal impressed at the points 54, 55.

In Fig. 4 the unbalance of the measuring circuit is noted at terminal points 80 and 81 and is converted to alternating current by input transformer 99 and converter 100 and shaped by the matched resistor-capacitor elements 101 and 102. The alternating current signal is then fed to two 12AU7 tubes 103 and 104 in tandem amplifying relationship, and thereafter the output from tubes 103 and 104 is delivered to the grids of two 12AX7 tubes 105 and 106. The greatly amplified signal is then fed to one winding 84a of the split phase motor 84 already mentioned (Fig. 2) the other winding 84b being energized from lines L3 and L4 of a 110 volt A.C. supply. Power transformer 107 has a primary 108 energized from lines L3, L4 with an optional adjustable tap 108a. Various secondary taps provide voltages where needed, for example taps 109 and 110 supply plate potentials of approximately 275 volts for the tubes 105 and 106, and taps 111 and 112 supply filament voltage for tubes 103 and 104. Since the amplifier's characteristics and circuits will be apparent to one skilled in the art, no further or more detailed description is necessary.

Summing up, at this point, the functions of motor 84, which responds to amplifier 30b shown in block outline in Fig. 2, and in circuit detail in Fig. 4, the motor operates (a) the moving slider on battery rheostat 77 (Fig. 3), (b) the sliding connector on rheostat 74 (Fig. 3), (c) a retransmitting slidewire connector on rheostat 113 (Fig. 2). The linkages for the operation of these controls are indicated in broken lines on Fig. 2. Terminals 96 and 97 already referred to as a source of constant voltage on Fig. 3 may now be again identified at the top right of Fig. 2 by means of the same reference numerals.

We have now rather fully explained the development of an electrical signal proportional to the amount of magnetic material travelling on a conveyor towards a coating drum, and the rendering of said signal operative on a motor 84 to perform certain further operations. We will now proceed to a description of the means whereby the amount of binder is controlled so as to be fed to the balling drum conveyor 21 in proper proportion to the amount of magnetic concentrate fed to the same conveyor.

Referring again to Fig. 2, a signal comprising a potential drop from terminal points 96 and 97 (Fig. 3) is applied at the similarly numbered points at the top right of Fig. 2 and is rendered effective on retransmitting slide wire resistor 113 through dropping resistor 116 and lines 117 and 118 to two points 119 and 120 of an electric bridge 114. Two opposed points 121 and 122 on the same bridge receive, through lines 123, 124 and 125, a signal from tachometer generator 35. This signal passes through dropping resistor 126 and voltage divider 137, the signal being proportional to the coal being mixed with the pellets.

Motor 84 is responding to any variations in the magnetic content of the concentrate and through the mechani-

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cal linkage with slide wire moving contact 113a the motor 84 varies the value of the constant voltage input at 96, 97 so as to transmit to the electrical bridge 114 a current to be balanced against the signal from generator 35. The resulting unbalanced status, if any, is transmitted through lines 124 and 125 to amplifier 126 whereby to operate a motor 127. Motor 127 through mechanical linkage 128 rotates to restore the balanced status by movement of the contact at 121 on the electric bridge, but also through another mechanical linkage 129 moves the slider on a proportional resistor 130 electrically associated with a standard electroline relay 131 the operation of which will be described in connection with Fig. 5.

Relay 131 operates motor 132 which through mechanical linkage 133 moves the sliding contact on potentiometer 134 which is in the field circuit of motor 28 through lines 135 and 136. Motor 28 operates the table feeder 27 which controls the binder feed from bin 26.

It will be apparent that the signal from the primary-secondary couple, representing variations in magnetic content of concentrate, has thus been integrated with the signal from the tachometer generator, representing the amount of binder being fed, and a predetermined ratio setting, electrical bridge 114, exerts a feed back control on the speed of binder feed motor 28. Putting it simply, if the pre-set equilibrium point of electrical bridge 114 is thrown out of balance by fluctuations signalled by the tachometer generator, then amplifier 126 magnifies the fluctuations, motor 127 operates to restore the balance, but concurrently motor 127 through relay 131 communicates the situation to motor 132, which latter motor regulates the speed of table feeder motor 28 to bring the binder feed to the desired value.

Still referring to Fig. 2, we show means for controlling the speed of the table feeder 24 for the concentrate feed. Motor 84 through mechanical linkage 140 moves the contact point of a proportioning resistor 141 of another electroline relay 142 which in turn responsively operates motor 143. This motor 143 through its linkage 144 operates the moving contact of a speed control potentiometer 145 in circuit with the field of motor 25 which operates the table feeder 24 for supplying concentrate. The hookup just described between motor 25 and motor 84 is arranged appropriately to be sensitive to variations in concentrate feed, and to restore the unbalance sensed by measuring device 30a (Fig. 3) and amplified by the amplifier 30b. Amplifier 30b and amplifier 126 are similar in structure and operation, as also are electroline relay devices 131 and 142 which will now be briefly described in connection with Fig. 5.

The relay actually shown in Fig. 5 is a conventional type, one such being obtainable from Minneapolis-Honeywell Regulator Company. The purpose of the relay is to accept a signal received at 141 (Figs. 2 and 5) and, responsive thereto, to deliver a current at terminals 146, 147, to become effective on motor 143. This operation involves control of proportional band, reset, and approach rate functions which are familiar to those skilled in the motor control art. It is not necessary to go into extended detail as to the manner of operation of the electroline relay control of a modutrol motor beyond the brief characterization now following.

A signal entering at terminals 151 and 152 becomes effective, through the various proportional band resistors 153, 154, 155, 156, 157 upon tube 158, the output of which is fed to tubes 159. There are interrelated modifying effects produced by heaters 160 and 161 in conjunction with electrical bridge 162, and the resultant signal is imposed on tubes 163 and 164. The ultimate effect, through the media of relay coils 165 or 166 operates contacts 167 or 168 respectively, and consequently controls the rotation of motor 22, in the case of electroline relay 142. Relay 131 functions similarly.

As we have explained hereinabove we have provided means for controlling the feed of concentrate and binder

to a predetermined proportion, the proportion being maintained even though the magnetic content of the concentrate varies. If the magnetic content does vary, then the concentrate feed is properly varied to restore the feed to a predetermined value, independent of its feeding characteristics, while still keeping the concentrate-binder ratio at the proper value.

Either an indicating or a recording means can be electrically or mechanically associated with the several controls described herein. The indicating means could be a pointer on a dial. The recording means could be a pen in contact with a moving or rotating chart. In Fig. 2 we have schematically illustrated these features and anyone skilled in the art of indicating and recording instruments can readily make the installation. We have indicated by broken line 170 an operative connection between modutrol motor 84 and an indicating and/or recording instrument 171. This instrument can be calibrated to directly show or inscribe the tons (or other weight unit) of concentrate passing the primary-secondary couple, as previously hereinabove described. Similarly modutrol motor 127 through linkage 172 and recorder 173 can show the ratio between concentrate and binder at any time. Finally, by an electrical or mechanical linkage 174 effective on indicator-recorder 175, the tachometer generator registers the actual weight of binder being delivered to the conveyor.

What is claimed is:

1. Apparatus of the character described comprising a source of a first material having magnetic characteristics, a moving conveyor, a first feeding means for controlling the flow of said first material from said source onto said conveyor, a first controller effective to control operation of said first feeding means, sensing means adjacent said conveyor and responsive to fluctuations in the magnetic characteristics of said first material carried on said conveyor, first electric circuit means operatively linking said first controller and said sensing means whereby to produce, in said first controller, operating fluctuations responsive to fluctuations in said sensing means and thereby to achieve uniformity in the quantity of magnetic material discharged on said conveyor, a source of additional material, a second feeding means for controlling the discharge of said additional material onto said conveyor, a second controller effective to control operation of said second feeding means, a second electric circuit means operatively linking said first controller and said second controller whereby to cause said second controller to respond proportionally to the aforesaid fluctuations in said first controller and thereby to cause variations in the rate of discharge of said additional material proportionally to any variations in the magnetic characteristics of said first material.

2. Apparatus as defined in claim 1 including, in combination therewith, a recorder, and means operatively associating said recorder and said first controller whereby to record the amount of magnetic material passing said sensing means, said recorder being calibrated to show said last named amount in units of weight.

3. Apparatus as defined in claim 1 including, in combination therewith a recorder operatively associated with said second controller whereby to record the amount of additional material delivered by said second feeding means, said recorder being calibrated to show said amount of said additional material in units of weight.

4. Apparatus as defined in claim 1 including, in combination therewith, recording means operatively associated both with said first controller and said second controller and adapted to continuously show the ratio of delivered magnetic material to delivered additional material.

5. Apparatus of the character described for automatically controlling the feed of an additional material to a conveyor carrying a magnetic material, said apparatus comprising means for moving said conveyor past a measuring zone, sensing means at said measuring zone re-

sponsive to variations in magnetic characteristics of said magnetic material, and adapted to transmit a signal proportionally varying with said variations, a source of magnetic material, a first feeding means for feeding magnetic material from said source onto said conveyor, a first motor effective to operate said first feeding means, a second feeding means for feeding additional material onto said conveyor, a second motor effective to operate said second feeding means, a first controller in electrical operative communication with said sensing means whereby to receive said varying signal, and effective upon said first motor to maintain at a constant value the feed of magnetic material, a second controller in electric operative connection with said second motor, said first controller being in electrical communication with said second controller whereby to cause said second controller to respond to any varying signal from said first controller and thereby to cause feed of said additional material to proportionally vary with feed of magnetic material.

6. Apparatus as defined in claim 5 including, in combination therewith, a quantity recorder, and means operatively associating said recorder and said first controller whereby to record the amount of magnetic material passing said sensing means, said recorder being calibrated to show said last named amount in units of weight.

7. Apparatus as defined in claim 6 including, in combination therewith, a recorder operatively associated with said second controller whereby to record the amount of additional material delivered by said second feeding means, said recorder being calibrated to show said last named amount in units of weight.

8. Apparatus as defined in claim 1 including, in combination therewith recording means operatively associated with both said first controller and said second controller, and adapted to continuously show the ratio of delivered magnetic material to delivered additional material.

9. Apparatus of the character described for automatically controlling the feed of a binding material to a conveyor carrying a magnetic concentrate material, said apparatus comprising means for moving said conveyor past a measuring zone, sensing means at said measuring zone comprising an electrical induction couple responsive to variations in magnetic characteristics of said magnetic concentrate material, and adapted to transmit an electrical signal proportionally varying with said variations in magnetic characteristics, a source of concentrate, a first feeding means for feeding concentrate onto said conveyor, a first motor effective to operate said first feeding means, a second feeding means for feeding binding material onto said conveyor, a second motor effective to operate said second feeding means, a first controller in electrical circuit communication with said sensing means whereby to be responsive to said varying signal, a tachometer generator operatively connected to said second motor means electrically connecting said first controller with said first motor whereby to impose on said first motor corrective variations responsive to variations in said varying signal and thereby to return to a constant value the concentrate feed, a second controller, means electrically connecting said second controller with said first controller whereby to transmit to said second controller a varying signal corresponding to the varying signal from said sensing means to said first controller, and means electrically connecting said second controller with said second motor and adapted to impose on said second motor operating variations responsive to variations in the signal originating in said sensing means whereby to produce variations in binder feed proportional to variations in concentrate feed.

10. Apparatus as defined in claim 9 including, in combination therewith, a quantity recorder, and means operatively associating said recorder and said first controller whereby to record the amount of magnetic concentrate passing said sensing means, said recorder being calibrated to show said last named amount in units of weight.

11. Apparatus as defined in claim 9 including, in combination therewith, a quantity recorder operatively associated with said second controller whereby to record the amount of binding material delivered by said second feeding means, said recorder being calibrated to show said 5 last named amount in units of weight.

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