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MAGNETIC MATERIAL FEED CONTROL

Filed June 9, 1958

5 Sheets-Sheet 1

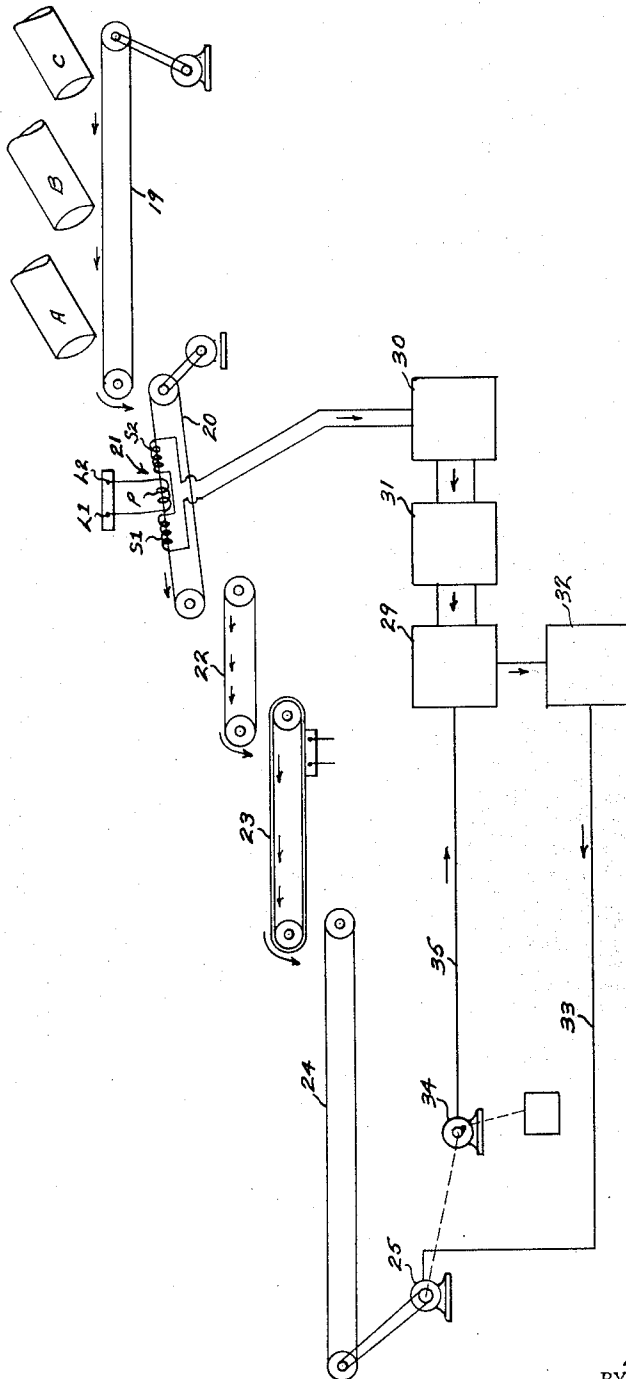


FIG. 1

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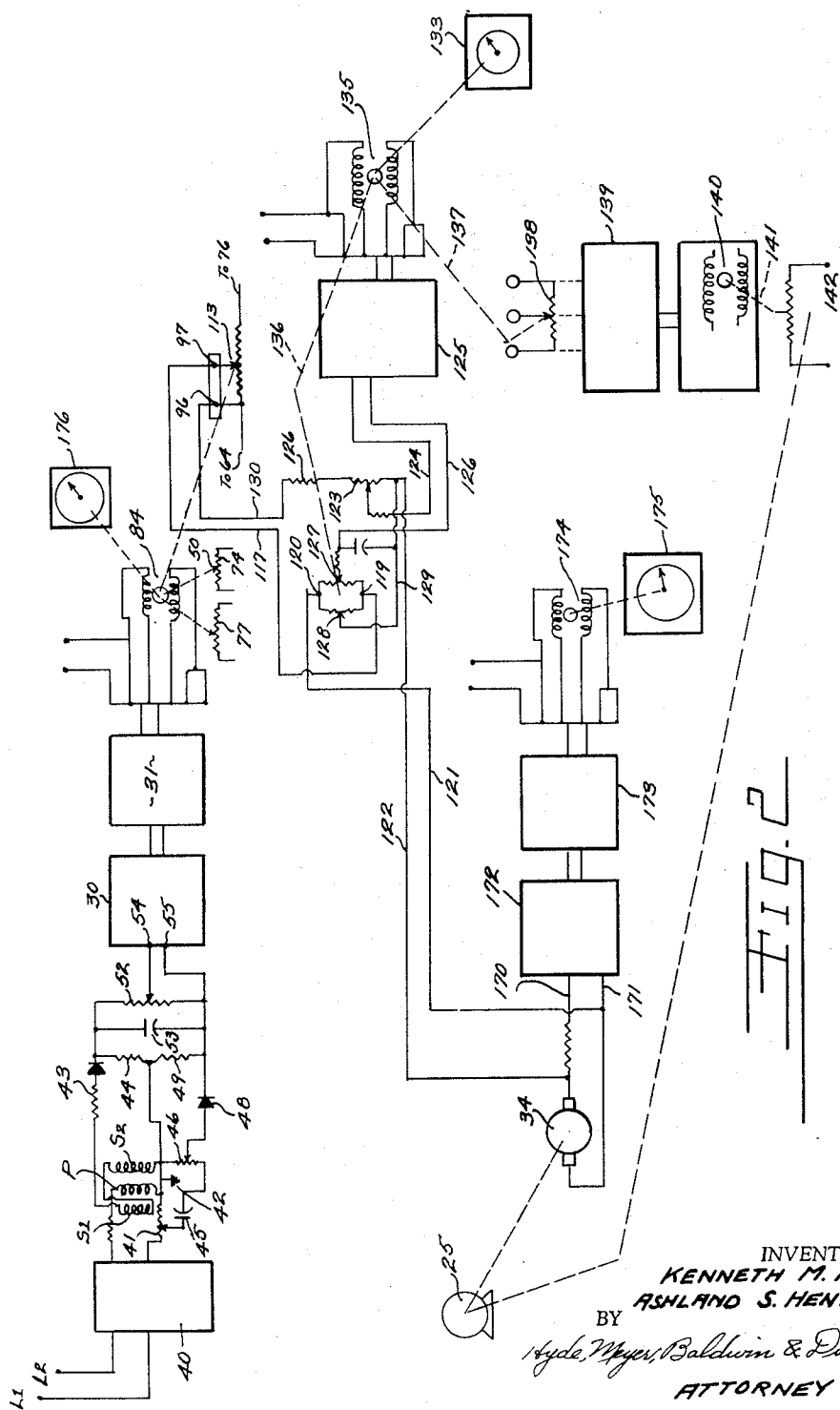
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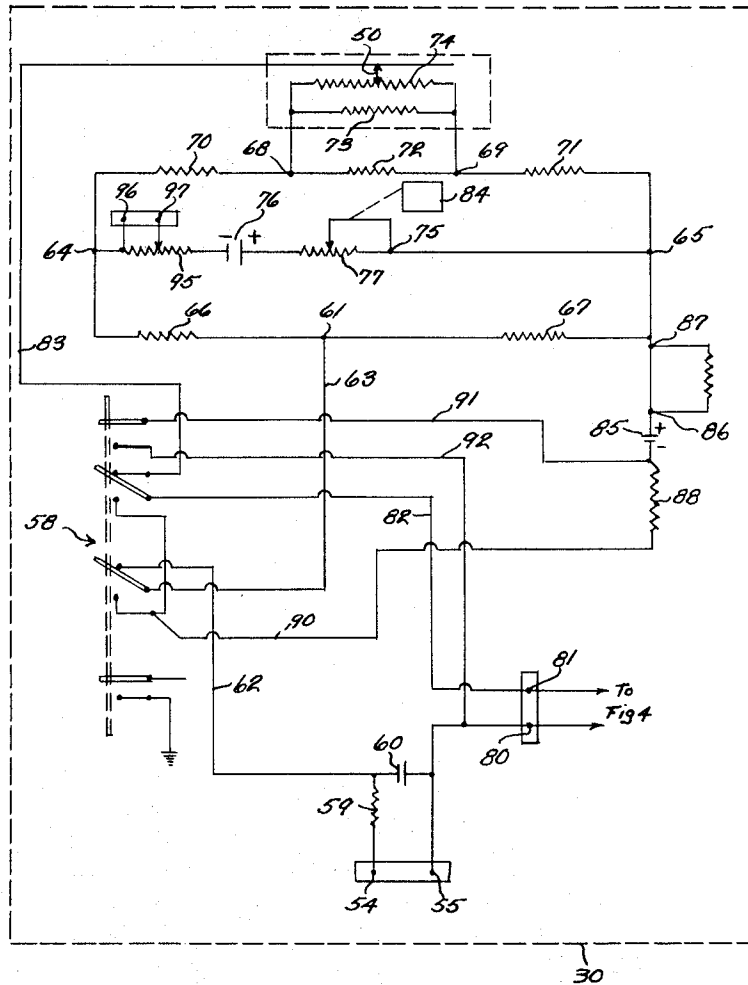


Fig. 3

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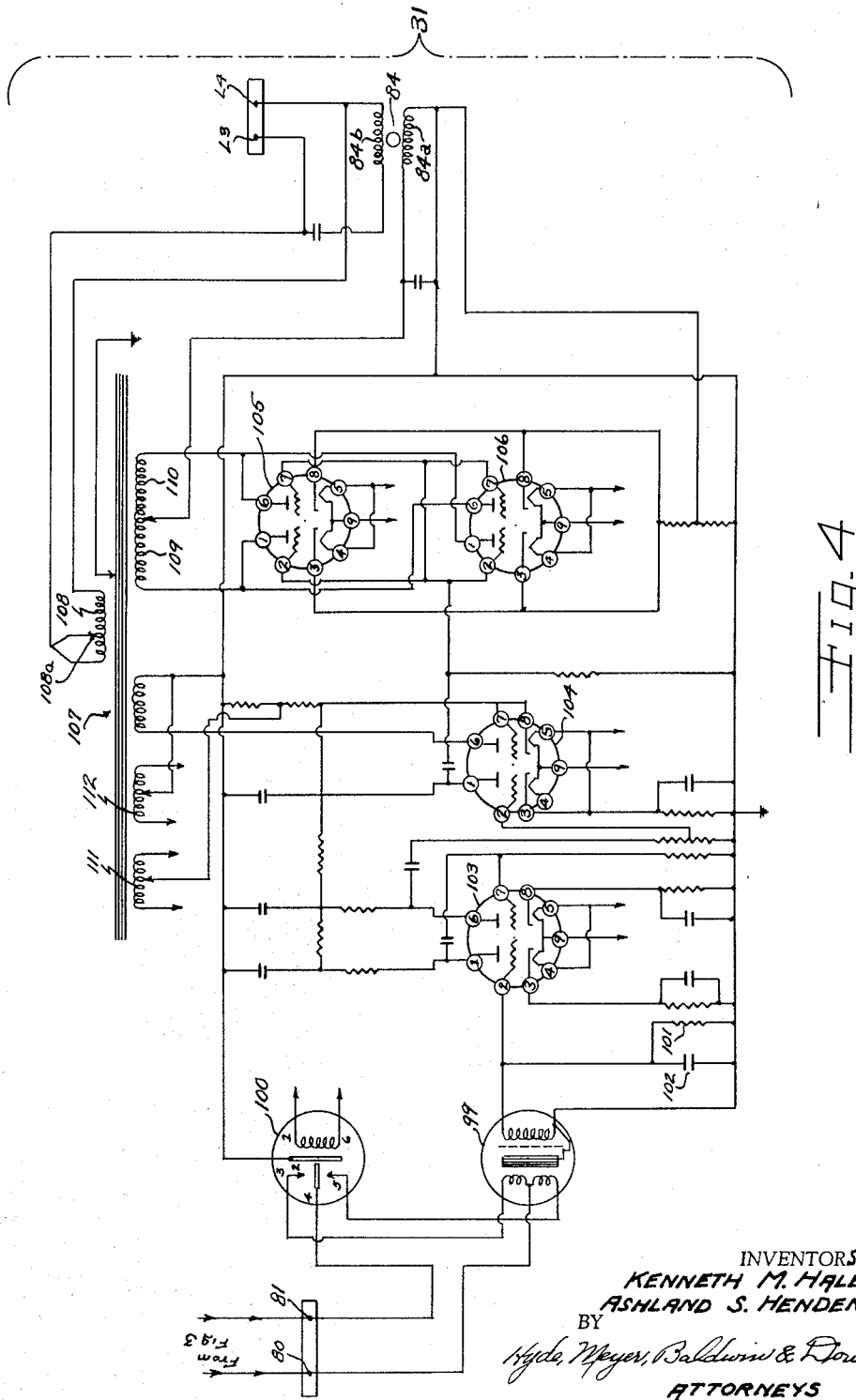
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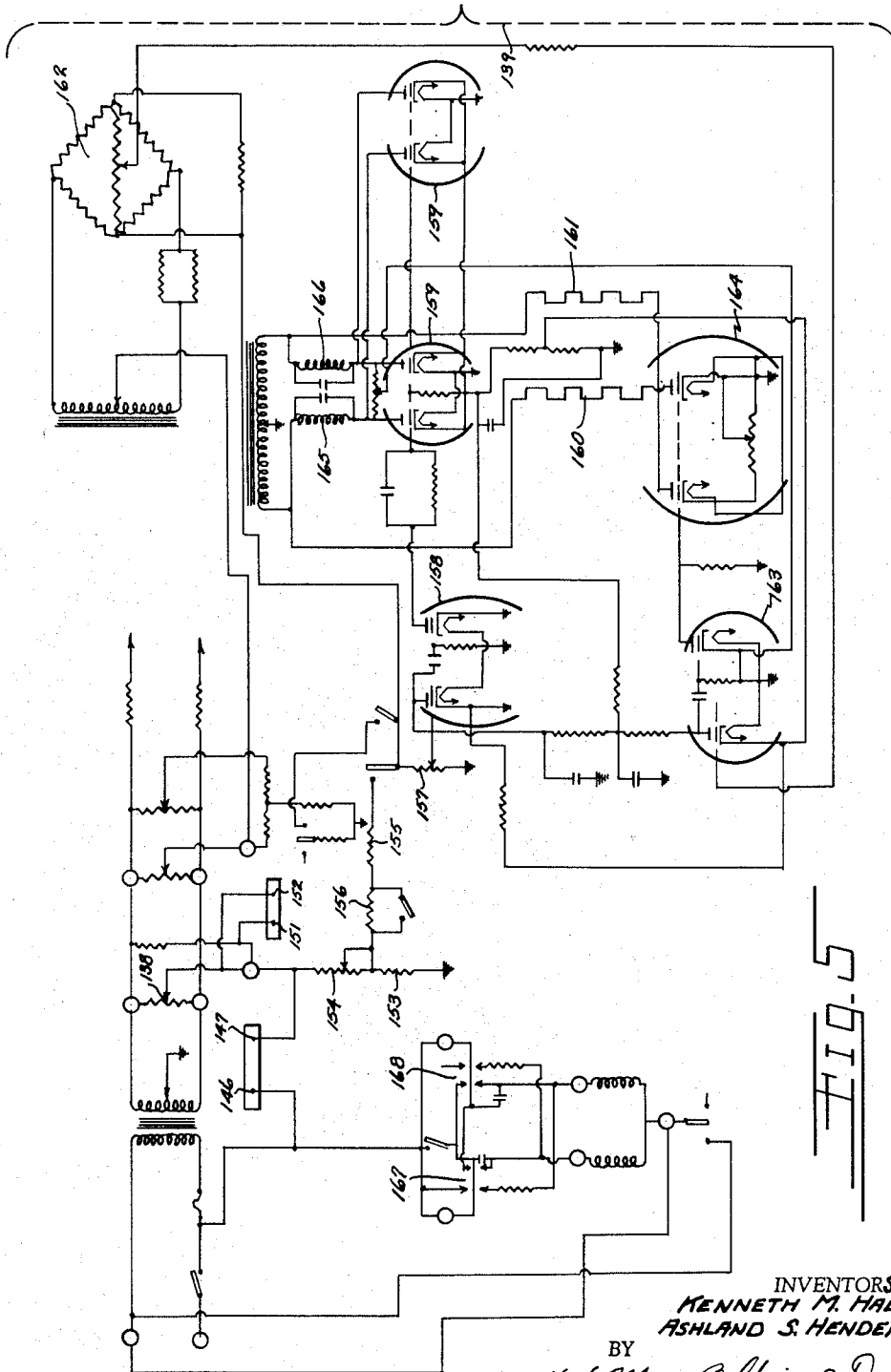
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MAGNETIC MATERIAL FEED CONTROL

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5 Sheets-Sheet 5



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MAGNETIC MATERIAL FEED CONTROL

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8 Claims. (Cl. 198—37)

The invention relates to a novel and improved method for controlling the feed of magnetic material to a treating zone. By way of example, and as an illustration of one embodiment of the invention, the method will be described in connection with the delivery of a uniform bed of pellets of beneficiated magnetic ferrous metal ore upon a conveyor moving continuously to and through an indurating furnace. As the amount of practically available iron ores of high iron concentration is gradually being depleted it becomes more and more evident that processes must be developed for beneficiating the lower grade ores. One such ore is taconite, an extremely hard rock which can be reduced to usable form by a series of crushing and separating steps not necessary to set out in detail here. For a proper understanding of the advantages of the invention it is believed desirable to give herein a brief resume of the pelletizing of beneficiated taconite ore.

The beneficiated taconite end product is in the form of a fine powder containing between sixty and seventy percent of iron in the form of a magnetic oxide of iron, having the formula Fe_3O_4 . This powder, or comminuted particles, is too fine for direct charging into a blast furnace since it would block the interstices of the blast furnace charge and prevent proper passage of the blast. It has been determined that the beneficiated taconite is most efficiently fed to the blast furnace in the form of small rounded agglomerated entities from about one-half inch to one and one-half inches in diameter. These entities variously known in the art by such terms as balls, nodules, or glomerules, will herein be identified by the convenient and also frequently used term "pellets."

A preferred method of pellet manufacture comprises moistening the pulverulent concentrate and rolling it into pellets in a large drum which is rotating on an axis somewhat inclined to the horizontal. The concentrate is charged into one end of the drum and rolls along the inner peripheral wall of the drum as it rotates. Nuclei form and increase in size as the growing particles progress towards the discharge end of the drum. The balling effect is analogous to the increase in size of a rolled snow ball on a snow slope. By various expedients not necessary to discuss here the pellet-forming procedure is controlled to yield pellets within the desired size range.

The beneficiated ore concentrate contains a certain amount of moisture, preferably around ten percent, which increases the tacky character of the powder to achieve improved balling properties. It may also contain a minor amount of some bonding material. The pellets, after formation, are subjected to rather vigorous handling. They must therefore be treated or indurated to increase their strength, hardness, and impact resistance, because in the progression from the pelletizing plant to the blast furnace they are transferred from conveyors to bins, thence perhaps to storage yards, thence to other conveying means, thence to ore-carrying boats, thence to railroad cars, etc. It is accordingly necessary that the soft moist pellets be given an induration treatment to prevent them from being substantially completely broken up by

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handling before they even reach the point of ultimate use.

This induration treatment has involved heating to an elevated temperature but preferably just below the range at which incipient fusion takes place. With beneficiated taconite a good operating upper limit is about 2400° F. If this temperature is materially exceeded incipient fusion and mutual adhesion occurs between the pellets, producing sintered lumps which are undesirable in subsequent reduction to metallic iron in the blast furnace.

Heating is supplied, for the most part externally. In one preferred system the pellets are disposed in a layer on an endless type of conveyor, consisting of a series of cars, moving in end-to-end contact through a pelletizing or induration furnace, and having a gas-permeable floor consisting of slightly spaced grate bars supported on pallets. The layer may be of any convenient thickness.

In the operation of the indurating furnace it has been quite difficult to supply pellets to the continuous conveyor at a uniform rate. This difficulty has given rise to many problems in producing a satisfactory quality and a high rate of production, among them the following.

Although the balling drum method of producing pellets is highly satisfactory, and is widely used, it has the disadvantageous feature that green pellets do not issue therefrom at a uniform rate. As a result the bed of pellets on the induration conveyor would be of nonuniform depth unless some control method or means is devised to insure a relatively even bed depth. A uniform bed depth is quite desirable because the indurating conveyor moves at a steady rate through the indurating furnace and if the bed depth varies, while the process and apparatus are pre-set for an average bed depth, the deeper portions of the bed will be incompletely or superficially burned while the shallower portions will be excessively burned. The pellet quality under such conditions would continuously vary, and a portion of the pellets would be unsatisfactory.

Efforts in the prior art practice have been directed towards the provision of a uniform bed depth, and various types of apparatus have been tried without too much success. The pellets contain an amount of moisture necessary to produce adhesion of their pulverulent contents, and by reason of this and other feeding and supply factors the eventual bed depth varies with variations in quantity feed. This condition, which is undesirable in a normal sintering operation, is more serious in an indurating furnace feed, because much higher air flows are used in pelletizing, and control of passage of air through the bed is a critical factor in proper induration, and variation in bed depth produces increase or decrease in bed resistance to air flow.

Assuming that all other induration factors have been controlled with a fixed bed depth in mind, it has been found that an increase in the fixed depth of about ten percent (or one inch in ten inches) will produce only superficial burning at increased depth, or over-treatment and perhaps undesired mutual adhesion when there is a ten percent decrease in the calculated bed depth.

Many methods have been devised in an attempt to produce a uniform bed depth. One such method involved the use of rods or probes depending into the bed to indicate the depth, in conjunction with manual or automatic means to correct the feed, when needed. This procedure is impractical in feeding pellets of the type here under consideration because the quantity of pellets being produced varies widely, and adjustments in speed of the machine cannot be made at a satisfactory rate of speed; that is to say by the time a correction has been made the undesirable condition exists along an extensive length of the conveyor. Furthermore the insertion of a probe into a moving bed of still-fragile pellets damages the ad-

jacent pellets and also induces an improper air distribution through the bed in the probed neighborhoods.

The primary object of the present invention is to deliver on a conveyor a uniform quantity of material having a magnetic component and being continuously fed to a treating zone.

A further object of the invention is to achieve this purpose without disturbing or otherwise affecting the material being conveyed.

A further object is to control the quantity of moist pellets being delivered to an indurating furnace without using any measuring means in physical contact with the wet and sticky pellets.

Another object of the invention is to provide a simple and effective method of varying automatically the quantity of magnetic material on a conveyor, and holding the quantity at any preset value regardless of variations in the quantity being fed to the conveyor.

Another object of the invention is to control the quantity of material fed to the indurating machine on the basis of dry weight of the material.

In the above recitation of objects of the invention it will be understood that a control of the quantity of the material necessarily results in a controlled bed depth since means is available, and known in the art, for distributing delivered material laterally on a conveyor in a uniform depth of bed, so that the crucial factor is the control of delivered quantity. While in the present specification, and actually in colloquial usage in the art, there is usual reference to control of bed depth, this usage actually recognizes the fact that bed depth control means delivered quantity control.

Other objects and advantages will be apparent from a study of the following specification, in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic showing of apparatus used in the practice of the present invention.

Fig. 2 is an electrical wiring diagram showing the operative relationship of the various electrical elements of the inventive control 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, pellets are formed in balling drums A, B, and C and delivered to a feed conveyor 19 and thence to a laterally oscillating conveyor 20 having quantity sensing means 21 which will later be described in detail. The pellets are then delivered to intermediate means in the delivery system, here merely schematically shown as a spreader conveyor 22 and a vibrating screen conveyor 23, being ultimately delivered to the main grate conveyor 24 which travels to and through the indurating furnace.

It will be understood that the character, number, and operative relationship of any conveying, spreading, or screening elements may be varied to suit particular situations. It is necessary however that there be feeding means provided with sensing means such as here identified by the reference numerals 20 and 21 respectively.

Conveyor 20, which is driven at constant speed, 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 and L₂. Variations in the amount of magnetic material passing axially through the primary coil produce corresponding and proportional variations in an alternating current induced in the secondary coils S₁ and S₂. These secondary variations are imposed on a ratio controller 29 through a measuring circuit unit 30 and an amplifier unit 31. These units will be more fully described in connection with Figs. 2 through 5.

The main grate conveyor 24 is driven by a variable speed motor 25 the speed of which is controlled from ratio controller 29 by means of a suitable control element

32 and circuit means 33. Motor 25 is operatively linked to a tachometer generator 34 which varies its electrical output signal proportionally to variation in speed of motor 25. This electrical output, through a circuit 35, is transmitted to the aforementioned ratio controller 29 where it is balanced against the signal from amplifier 31 which, as previously indicated, is proportional to the amount of magnetic material travelling on conveyor 20. The resultant of the integration of the two inputs to ratio controller 29 is fed to control element 32, the output of which determines whether motor 25 should be accelerated or slowed down.

As a brief resume, the inductive couple is sensitive to variations in the amount of magnetic material in the burden on conveyor 20. The output signal of the couple secondary is balanced against the output signal of generator 34 which is proportional to the speed of main conveyor 24. If the integration of these two signals indicates the feed signal to exceed a preset norm, then conveyor 24 is speeded up to handle the increased supply. If the speed signal exceeds the same norm then conveyor 24 is slowed down until the proper integration balance is again attained. How this is done will be explained in detail in the description of Figs. 2 through 5.

Means is provided to show, in actual weight units, the amount of magnetic material being conveyed on the main grate. The inductive couple is sensitive only to the actual magnetic content of the material, and variation in moisture content, or other nonmagnetic content, does not affect the inductive couple. The secondary signal may therefore be properly characterized as a dry-weight signal, and indicating means responsive to this signal can be calibrated in actual units of weight.

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 S₁ and S₂ which in a structural assembly are axially spaced one on each side of the primary. The conveyor 20 (Fig. 1) passes axially through the couple, and any magnetic material thereon increases the induced current in S₁, S₂. An A.C. current from L₁, L₂ feeds into a constant voltage transformer 40 through a resistor 41 into primary P. One side is grounded at 42. The voltage developed in S₁, S₂ 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 amount 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 an adjustable 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, consisting respectively of a measuring circuit and an amplifier, these items being incorporated in the blocks marked 30 and 31 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 cell which, when used only as an occasional check means, remains at constant E.M.F. for a long period. We have provided a multiple throw switch 53 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, to be more fully described in connection with Fig. 4, is in series with terminals 80 and 81, and 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) as will appear. It may now be stated that the function of motor 84 is to operate the sliding contact 50 on resistor 74 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 down 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 58 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 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 (Fig. 2).

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 any 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 31 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 50 on rheostat 74 (Fig. 3), (c) a retransmitting slidewire connector 113 (Fig. 2) movable on resistor 95, (d) an instrument 176 to record dry weight of material moving on conveyor 20. The linkages for the operation of these controls are indicated in broken lines leading from motor 84 in 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, and the rendering of said signal operative on a motor 84 to perform certain further operations.

Referring again to Fig. 2 we show means whereby the movement of motor 84 representing an unbalance caused by a variation in magnetic content on feeder conveyor 20 moves retransmitting slidewire contact 113 with the following results. A variable potential derived from terminals 96 and 97, and already mentioned in connection with the similarly numbered terminals in Fig. 3, is effective on a ratio-determining circuit wherein a signal from

tachometer generator 34 is integrated with the variation in the potential from terminals 96 and 97 as caused by variation in the moving slidewire contact. The integrating circuits are as follows. From terminal 97 and the slide wire resistor contact 113 through line 117 to point 119 on the balancing bridge. The corresponding opposed point 120 on the bridge is connected through line 121 to the tachometer generator 34. The return line 122 is connected through voltage divider 123 and line 124 to the primary of an input transformer in amplifier 125. The return line 126 from said primary terminates at point 127 on the balancing bridge. The balancing circuit is completed from bridge point 128 through line 129 voltage divider 123, resistor 126 and lines 130 to terminal 96.

Assume for the moment that a predetermined balance exists between the main conveyor speed, as reflected in the signal from tachometer generator 34, and the feed of magnetic material through the inductive couple, as reflected by the position of the slidewire resistor contact point, so that the voltage from terminals 96 and 97 is exactly balanced through the bridge against the tachometer voltage. If then there is a variation in magnetic content passing through the inductive couple a signal will be generated, measured and amplified and will cause motor 84 to move the slidewire contact. The resulting unbalance is effective on the primary of the input transformer of amplifier 125, which is identical with amplifier 31 already described in connection with Fig. 4.

The output of amplifier 125 is effective on a motor 135 which rotates to produce a three fold effect. In the first place it operates a physical linkage indicated by broken line 136 to move the sliding point 127 on the balancing bridge towards a restored balance. In the second place it operates another mechanical linkage indicated by broken line 137 to move a slider on a proportional resistor 138 electrically associated with a standard electroline relay 139 the operation of which will be described in connection with Fig. 5. In the third place it operates a dial indicator 133, as will appear.

Relay 139 operates a motor 140 which, through linkage indicated by broken line 141 moves the sliding contact on a potentiometer 142 which is in the field circuit of main conveyor motor 25. Motor 25 is consequently varied in speed responsive to variations in the magnetic content of the feed supply on distributor conveyor 20.

Putting the matter simply, if the pre-set equilibrium point of the electrical bridge is thrown out of balance by fluctuations signalled by the tachometer generator then amplifier 125 magnifies the fluctuations, motor 135 operates to restore the balance, but concurrently motor 135 through relay 139 communicates the situation to motor 140, which latter motor regulates the speed of main conveyor motor 25 to maintain the conveyor burden at a constant quantity, and consequently a fixed bed depth.

In Fig. 2, at the extreme right, we show an indicating instrument 133 which is operated by motor 135 as indicated by the broken line therebetween, representing a mechanical linkage. Since operation of motor 135 is responsive to the integrated signal coming on lines 124, 126 (Fig. 2) amplified by amplifier 125, the motor 135 moves to an extent which is a resultant of the speed of pelletizing grate conveyor 24 (sensed by tachometer-generator 34) and the weight signal (sensed by the inductive couple P, S₁, S₂). Motor 135 therefore can operate the indicating and/or recording instrument 133 which shows weight of pellet material passing a fixed point per unit of time. Assuming a relatively level bed, the dial of instrument 133 can be calibrated to show pellet bed depth in inches.

Reference has been made above to the interposition of relay 139 in the sequence of operation. This relay, shown in detail in Fig. 5 is a conventional type, obtainable commercially. The purpose of the relay is to accept

a signal received at 138 (Figs. 2 and 5) and, responsive thereto, to deliver a current at terminals 146, 147, to become effective on motor 140. 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 and 166 operates contacts 167 or 163 respectively, and consequently controls the rotation of motor 140.

Referring again to Fig. 2 we show means for maintaining a continuous visual check, or, if desired, a graphic record of the speed changes of the main conveyor as controlled by the means already described. A circuit represented by the lines 170 and 171 (lower left corner of Fig. 2) delivers a signal originating in tachometer generator 34 to a measuring circuit 172 which is identical with the one already identified by reference character 30 (at the top of Fig. 2) and shown in detail in Fig. 3. The resulting current is amplified in the amplifier 173 which likewise is identical with the amplifier shown at 31 (top of Fig. 2) and shown in detail in Fig. 4. Any current originating in the measuring circuit 172 represents an imbalance above or below a pre-established mean, and any such current when applied to the field of Modutrol motor 174 causes this motor to operate a pointer or a pen on an indicator or recorder 175 so as to give a visual indication in linear units of conveyor travel per unit of time, such as inches or feet per minute.

Finally, the control means herein disclosed may be equipped to show, in units of weight, the actual quantity of magnetic material travelling on the conveyor 20. For this purpose we provide an instrument of the dial indicator type, which may also include a pen travelling relative to a chart. This instrument, schematically shown at 176 in Fig. 2, is operatively linked to motor 84 by a mechanical linkage shown as a broken line between motor 84 and the indicating instrument 176. Since it will be obvious that the inductive couple P, S₁ and S₂, yields a signal proportional to the amount of magnetic material, and since this signal, after amplification, is effective on motor 84, the instrument 176 can be calibrated to render a correct reading, in avoirdupois units, of the amount of magnetic material passing on the conveyor 20. These units represent dry weight since the sensing and control means hereinabove described does not respond to quantity of moisture or other non-magnetic component of the burden passing the sensing means.

What is claimed is:

1. Apparatus of the character described for conveying a controlled and uniform quantity of magnetic material to a processing zone, said apparatus comprising a main conveyor having a portion thereof passing through said processing zone, a variable speed driving motor for driving said conveyor, a source of magnetic material, material delivering means for receiving magnetic material from said source and routing it past a measuring zone and onto said main conveyor, sensing means at said measuring zone responsive to variations in magnetic characteristics of said magnetic material, an integrating controller for comparing incoming first and second electric signals and emitting an outgoing electric signal representative of any energy differential between said incoming signals, a tachometer generator, means operatively linking said tachometer generator with said driving motor whereby said tachometer generator emits a first electric signal

proportional in intensity to the rotational speed of said driving motor, a first electric circuit means operatively associating said tachometer with said integrating controller for conveying said first signal to said integrating controller, a second electric circuit means operatively associating said magnetic-characteristic sensing means with said integrating controller for conveying said second signal to said integrating controller, said outgoing signal from said integrating controller being effective on said driving motor whereby to vary the speed thereof responsive to the intensity and character of said outgoing signal.

2. Apparatus as defined in claim 1 wherein there is provided, in combination therewith, variable resistor means in circuit with the field windings of said driving motor, and means responsive to said outgoing signal and effective on said variable resistor to vary the electric current supplied to said field windings.

3. Apparatus as defined in claim 1 including, in combination therewith, an indicating means adapted to register units of linear travel per unit of time, and means operatively linking said indicating means with said tachometer generator whereby said indicating means shows the rate of travel of said main conveyor.

4. Apparatus as defined in claim 1 including, in combination therewith, a quantity recorder, and means operatively associating said recorder and said integrating controller whereby to record the amount of magnetic material travelling on said main conveyor per unit of conveyor area per unit of time, said recorder being calibrated to show said amount in units of weight.

5. Apparatus as defined in claim 1 wherein there is provided a weight indicating instrument calibrated to read in weight of magnetic material, and means operatively linking said weight indicating instrument with said sensing means whereby to show weight of magnetic material per unit of main conveyor area.

6. Apparatus of the character described for conveying a controlled and uniform quantity of magnetic material to a processing zone, said apparatus comprising a main conveyor having a portion thereof passing through said processing zone, a variable speed driving motor for driving said conveyor, a source of magnetic material, material delivering means for receiving magnetic material from said source and routing it past a measuring zone and onto said main conveyor, sensing means at said measuring zone responsive to variations in quantity of said magnetic material, an integrating controller for comparing incoming first and second electric signals and emitting an outgoing electric signal representative of any energy differential between said incoming signals, a tachometer generator, means operatively linking said tachometer generator with said driving motor whereby said tachometer generator emits a first electric signal proportional in intensity to the rotational speed of said driving motor, a first electric circuit means operatively associating said tachometer with said integrating controller for conveying said first signal to said integrating

controller, a second electric circuit means operatively associating said sensing means with said integrating controller for conveying said second signal to said integrating controller, said outgoing signal from said integrating controller being effective on said driving motor whereby to vary the speed thereof responsive to the intensity and character of said outgoing signal, said integrating controller including electric bridge balancing means of the general wheatstone type wherein said first and second signals are opposed and balanced.

7. Apparatus of the character described for conveying a controlled and uniform quantity of magnetic material to a processing zone, said apparatus comprising a main conveyor having a portion thereof passing through said processing zone, a variable speed driving motor for driving said conveyor, a source of magnetic material, material delivering means for receiving magnetic material from said source and routing it past a measuring zone and onto said main conveyor, sensing means at said measuring zone responsive to variations in quantity of said magnetic material, an integrating controller for comparing incoming first and second electric signals and emitting an outgoing electric signal representative of any energy differential between said incoming signals, a tachometer generator, means operatively linking said tachometer generator with said driving motor whereby said tachometer generator emits a first electric signal proportional in intensity to the rotational speed of said driving motor, a first electric circuit means operatively associating said tachometer with said integrating controller for conveying said first signal to said integrating controller, a second electric circuit means operatively associating said sensing means with said integrating controller for conveying said second signal to said integrating controller, said outgoing signal from said integrating controller being effective on said driving motor whereby to vary the speed thereof responsive to the intensity and character of said outgoing signal, said sensing means consisting of a primary-secondary inductive couple including annular primary and secondary coils, and said material delivery means passing through said annular coils.

8. Apparatus as defined in claim 7 wherein said primary coil is independently energized from a constant source of varying current, whereby the induced current in said secondary coil varies in intensity dependent on the magnetic flux characteristics of the material moving on said material delivery means.

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UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

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November 29, 1960

Kenneth M. Haley et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 39, for "detremined" read -- determined --;
column 2, line 6, for "tmeperature" read -- temperature --;
line 26, for "induration" read -- indurating --; column 3,
line 64, for "siutable source of alternating of" read -- suitable
source of altering or --; column 4, line 73, for "sucecssion"
read -- succession --; column 5, line 22, for "intermediae"
read -- intermediate --; column 9, line 56, for "techometer"
read -- tachometer --.

Signed and sealed this 2nd day of May 1961.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents