

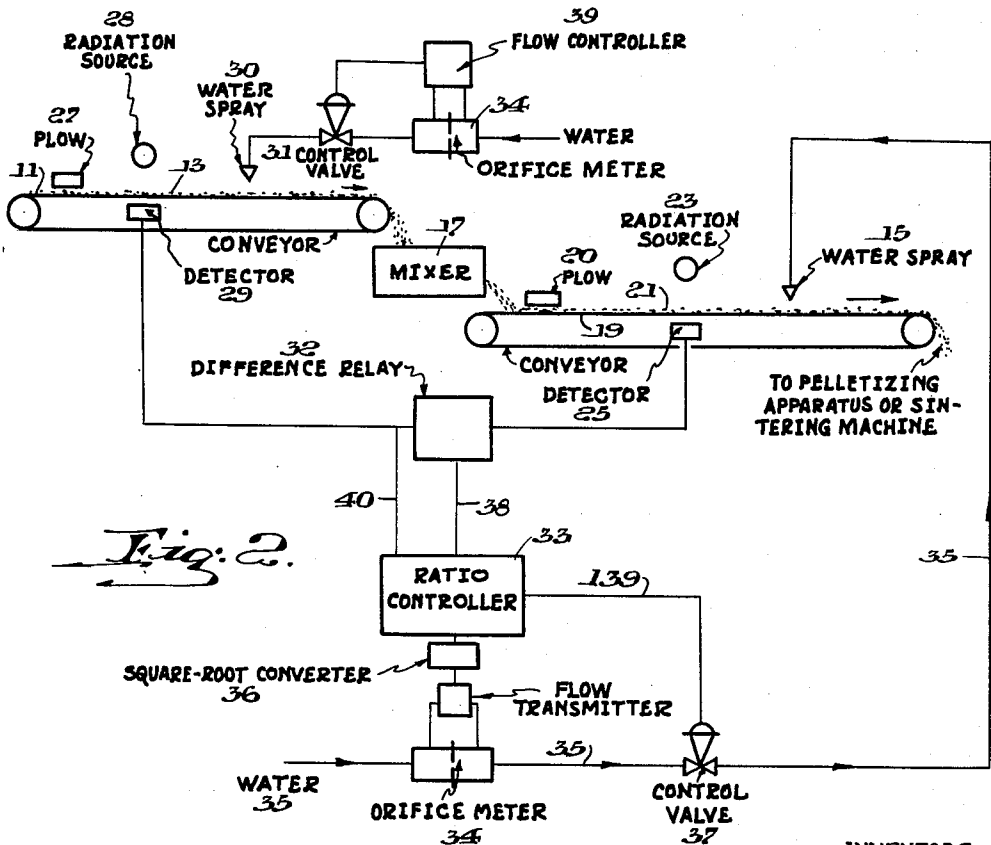
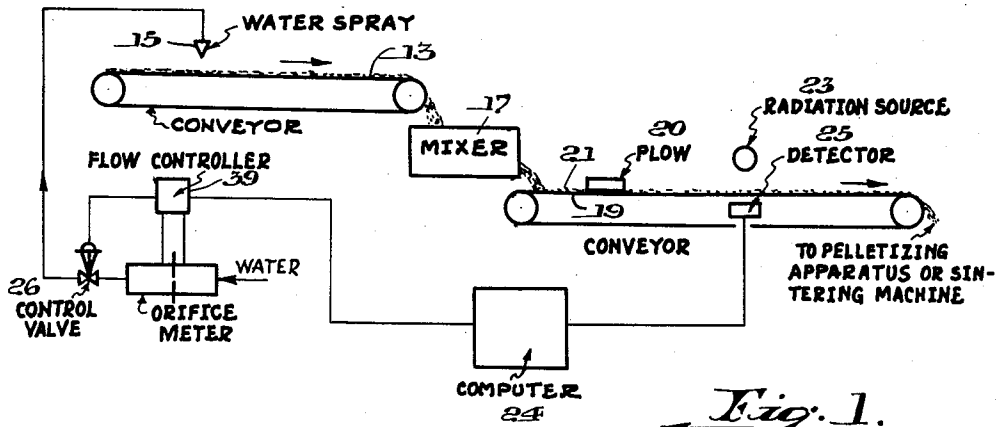
Sept. 15, 1964

S. MACDONALD ET AL
METHOD AND APPARATUS FOR MEASURING AND
CONTROLLING MOISTURE IN A SINTER MIX

3,148,971

Filed Feb. 14, 1961

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

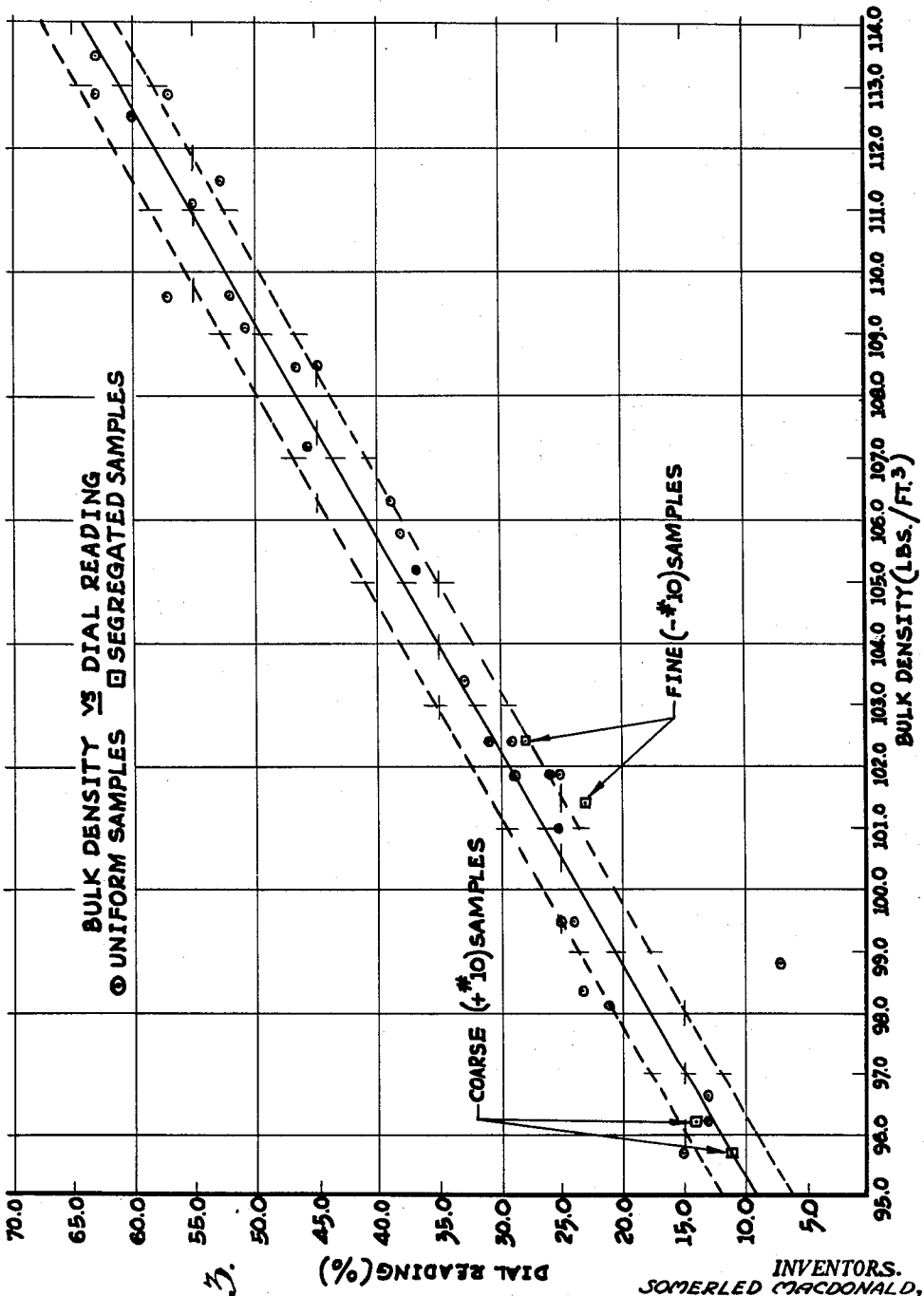


Fig. 3.

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4 Sheets-Sheet 3

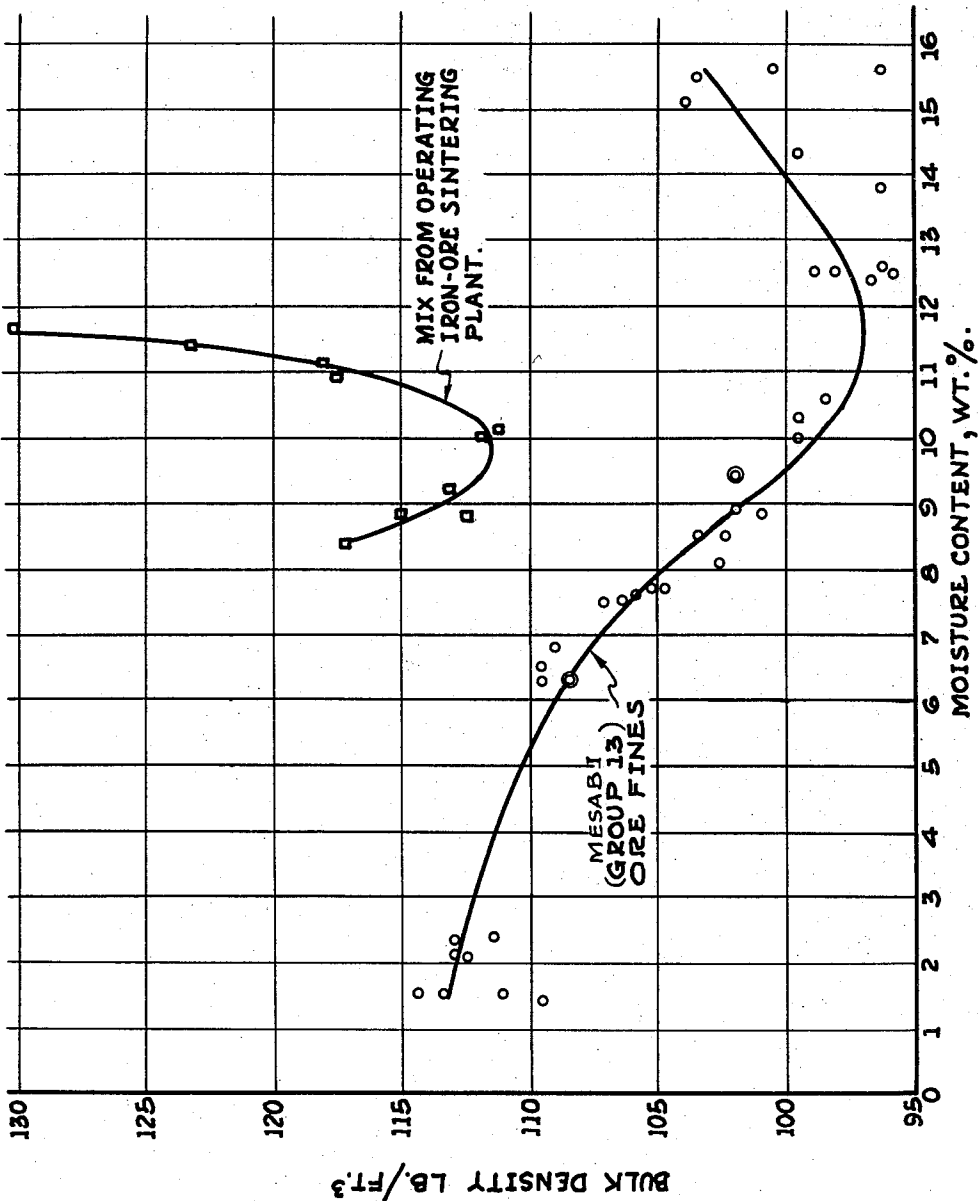


Fig. 1.

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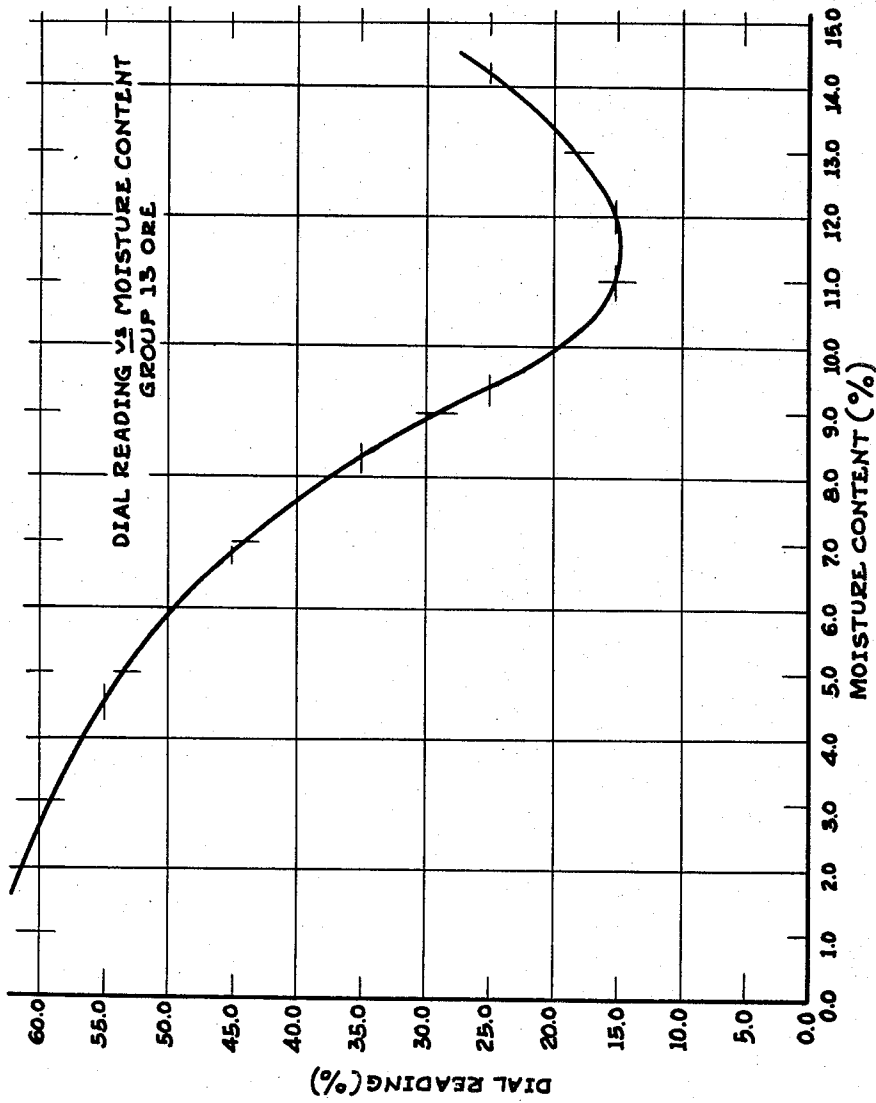


Fig. 5.

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METHOD AND APPARATUS FOR MEASURING AND CONTROLLING MOISTURE IN A SINTER MIX

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Filed Feb. 14, 1961, Ser. No. 89,145

2 Claims. (Cl. 75—5)

This invention relates to a method and apparatus for measuring and controlling the moisture content in a sinter mix of solid material to be supplied to a sintering step, and more particularly, to a method and apparatus for measuring and controlling the moisture content in the sinter mix preparatory to the sintering thereof on travelling grates.

Sintering on travelling grates has been an important method of beneficiating finely-divided ferrous and nonferrous ores. The ferrous ores sintered include flue dust, sinter return fines, mill scale, pyrites, aniline sludge and iron ores, such as hematite, magnetite, limonite, and siderite. The nonferrous ores sintered include manganese ore, zinc ore, lead ore, and nickel ore. Minerals such as limestone aggregates, phosphate rock, clay, grinding effluent, a by-product from the plate glass industry, boiler fly ash, coal mine refuse and fuels, such as finely-divided coal or coke, are also included to form a sinter mix for travelling grates.

In travelling grate sintering operations, air is passed through a dampened sinter mix and grate while the mix is travelling with the grate, to burn the fuel in the mix and thus provide the heat to agglomerate the ore into sinter by thermal bonding.

Therefore, it is necessary to treat the sinter mix prior to the sintering thereof to improve its permeability to passage of air through the mix when on the grate because when untreated, the permeability of the mix when on the grate is of such a small degree that the sintering rate of the untreated sinter mix is too slow.

In any travelling grate sintering operation the maximum possible permeability of the bed to air and waste gases from the burning of the fuel in the mix is necessary because the sintering rate is a direct function of this permeability. In those cases, particularly in older plants, where no balling or pelletizing apparatus is used, the bed permeability is a function of the moisture content of the mix which has been fluffed up in some sort of mixing apparatus such as a pug mill. In the case of most modern plants, the moistened sinter mix, or part of it, is passed through either a multiple cone balling drum, a standard balling drum, a disc pelletizer or some other apparatus which can roll the moist mix into small balls. This balling or pelletizing results in considerable improvement in bed permeability and sintering rate on the grate over the older methods. Controlling the moisture content of the mix within rather narrow limits, before it enters the pelletizing apparatus, is necessary in order to obtain balls of the optimum size to produce strong sinter at the highest possible rate. Since the moisture content of sinter mixes, with and without balling, is of great importance, some instrumentation, either complete or semi-automatic, which will effectively control the moisture in the feed to the pelletizing apparatus before the grate, or in the feed to the sintering machine grate if no pelletizing apparatus is used is, of course, necessary to this industry. Consequently, methods have been developed to increase the permeability of the mix before it reaches the sinter grate. Heretofore, the methods of treatment have been to add small amounts of water to the sinter mix and to fluff the moistened sinter mix in a pug mill before the sinter grate, or to add water to sinter mix as the binder for balling or

pelletizing, and to then pass the moistened mix through balling or pelletizing drums; and more particularly, to a multiple cone balling drum to pelletize or nodulize the mix, as disclosed in United States Patent No. 2,920,344, to Harold T. Stirling, issued on January 12, 1960, and entitled, "Balling Drum." Disc pelletizers and other apparatus have also been used to roll the mix into small balls with a liquid binder, such as water, whereby, to increase the permeability of sinter mix appreciably.

The amount of moisture in a sinter mix has a significant influence on the maximum rate of production of sinter that can be achieved on a sinter grate and has an effect on the quality of the sinter product, and so control of the amount of moisture in the sinter mix is desirable to permit uniform operation either with or without balling.

At the present time, moisture determinations are made manually from samples taken from the material mix that is being charged onto the pallets, but measurement of variations in the moisture content of the mix cannot be made rapidly enough as it comes to the sintering machine to permit fully effective adjustment of the moisture content to the desired value by increasing or decreasing the amount of water added to the mix before the grate. Attempts have been made to monitor continuously a variable which is related to moisture and, by proper calibration, convert the measurement to a measurement of moisture. Electrical probe systems to measure the conductivity do not properly interpret and use this information as to moisture content because the conductivity of the mix does not bear a fixed relation to the amount of moisture present in the mix. The conductivity of the mix is influenced also by the chemical constituents of the mix, the bulk density and texture of the mix, the condition of the probes, etc., and the resulting readings are not sufficiently accurate to form the basis for a satisfactory moisture control system for sinter mixes for sintering machines. Consequently, the moisture content of the sinter mix on the grate varies widely as does the sinter rate and the sintering operation is expensive due to the necessity of employing a person at all times to manually inspect the sinter mix and to determine manually the necessary amount of liquid to be added in order to control the amount of water addition to the liquid.

It is an object of this invention, therefore, to provide an improved method and means for measuring and controlling the water additions to a sinter mix before sintering, to maintain a minimum density of the sinter mix before the grate for greater permeability of the sinter mix on a grate in sintering.

This invention contemplates the addition of liquid water to the mix before the sinter grate, conveying the moistened mix in a continuous stream, leveling the stream, directing gamma radiation, and more particularly, gamma rays of radioactive isotopes through the stream, detecting the amount of radiation that penetrates the stream, forming thereby a signal proportional to the radiation passing through the stream, and operating control means by and in accordance with the signal produced to actuate means to add the aforesaid liquid water to the sinter mix until a predetermined degree of such radiation is received through said stream, thus imparting to the mix the moisture content for a predetermined degree of minimum bulk density of the mix. The moisture content for a specific minimum bulk density, and the degree of penetration of such radiation for a mix of the specific minimum bulk density can be determined either manually from box samples, or completely automatically by known apparatus means.

More particularly, in accordance with this invention, as the water is mixed with dry or insufficiently wet sinter mix, the bulk density of the mix decreases to a greatest minimum point at which the addition of more water may

instead suddenly cause the bulk density of the mix to increase toward a greatest maximum bulk density. It has been found surprisingly that the required moisture content for balling or pelletizing of the mix to attain optimum permeability of the mix in the form of balls or pellets as by means of balling drums, or the like, falls within about plus or minus one percent of the percentage of moisture content that corresponds with the greatest minimum bulk density of sinter mixes.

Other objects and advantages of the invention will be apparent as it is better understood from the following description, when considered in connection with the accompanying drawings illustrating the best mode of practicing the same:

FIGURE 1 is a partial isometric view of apparatus embodying this invention;

FIGURE 2 is a schematic drawing of another control system for carrying out this invention;

FIGURE 3 is a straight line graph correlating bulk density with the dial reading of a dial calibrated to read bulk density, in accordance with the invention;

FIGURE 4 shows two graphs showing the relationship between bulk density and moisture content for fines according to this invention;

FIGURE 5 shows a single graph correlating dial reading with moisture content in practicing the invention.

The same reference numerals are used for like parts in each of the several views. Referring to FIGURES 3 to 5: A system proposed by V. V. Greg, which utilizes a gamma-ray source and an ionization chamber detector to regulate the bulk density of coal mixes for coke ovens which, as described and claimed in his copending application Serial No. 24,026, filed April 22, 1960, entitled, "Bulk Density Control," has been found effective for producing the required changes in bulk density of such coal by the addition of oil and water to the coal. The radiation source-detector combination can actually measure changes in the mass through which the rays travel and can be correlated with bulk density by maintaining a constant depth through which rays pass which are confined within a constant cross-section.

After observing some of these tests, the present inventors felt that such a gamma-ray system could be used for the semi or complete automatic control of the moisture content of sinter mixes, since if such a system could measure bulk density of coal and adjust the flow of oil or water to control this bulk density, then it might be possible to regulate the moisture content of sinter mixes by measuring bulk density which should be some function of moisture content.

Accordingly, an initial series of tests was run to investigate the possibility of using gamma rays to determine the moisture content of ores. In these tests, United States Steel, Mesabi (Group 13), ore fines were used for the tests since they are considered typical. It was found that the test machine could be calibrated to read bulk densities of sinter mix material within the limits of plus or minus one pound per cubic foot, regardless of average particle size in the mix. A straight-line graph, correlating bulk density with dial reading (percent of ammeter scale) on the instrument is shown in FIGURE 3. It was also found that bulk density actually could be correlated with moisture content when using a sinter mix with constant particle size. A graph of these variables does not produce a straight line, however. The lower graph shown in FIGURE 4 shows the relationship between bulk density and moisture content for the Mesabi (Group 13) ore fines. Also, the curve goes through a point of greatest minimum bulk density at about 11½ percent water. It was found that the desired moisture content for optimum balling for this typical ore falls within plus or minus one percent of moisture from that corresponding to the greatest minimum bulk density on this curve. When the feed to the sintering plant is not to be pelletized, it was

found that the optimum moisture content is below that required to give the greatest minimum bulk density.

The line, which relates dial reading to bulk density in the graph of FIGURE 3 and the curve, which relate bulk density to moisture content in the graphs of FIGURE 4, can be combined to give curves correlating dial reading with moisture content. This has been plotted as the single graph of FIGURE 5 as to the Group 13 ore fines of the lower curve in FIGURE 4. Thus, we conceive that any control instrument utilizing gamma rays produced by radioactive isotopes can, in effect, be set up to transpose moisture content into some kind of signal, i.e., current from an ionization-chamber detector, which would be a function of a curve similar to this latter curve.

Referring to FIGURE 1, there is illustrated schematically the simplest method (1) for controlling moisture using this apparatus to (a) completely automatically maintain the lowest point on the bulk density versus moisture curve regardless of shifts in the plotted location of this curve due to changes in the mix, and (b) semi-automatically only when the desired quantity is well short of the greatest minimum on the curves FIGURE 4. Controlling the moisture completely automatically is done with this system only when the computer is used which will automatically find and hold the lowest point on the bulk density versus moisture curves of FIGURE 4. Semi-automatic control is done without the computer 24, and this is satisfactory for controlling moisture only when the desired quantity of moisture is well short of the lowest minimum on the curves. Operation without the computer is used only when the mix is not to be balled or pelletized since the correct moisture for balling or pelletizing is always near the bottom of the curves. Thus, with a shift in the curves due to a change in mix, only the computer method of control will find and hold at the new low point with changes in the mix. It is unlikely, however, that the change of mix in a given plant would ever cause changes or shifts in the location of the curve which are as pronounced as those shown by the two curves shown in FIGURE 4.

The material on the conveyor belt 11 passes under a water spray 15 before entering the mixing apparatus 17. When a pelletizing apparatus is to be used, the mixing by mixer 17 would probably not have to be more complicated than a junction chute or a belt mixer. In this case, some of the more coarse constituents of the sinter mix, such as the returns, would probably be added to the sinter-feed stream 13 after the pelletizing step in order to reduce the moisture content of the mix after the balls have been formed. If the sinter feed is not to be pelletized, the mixing apparatus 17 would probably consist of a pug mill. In this case, all the constituents of the sinter feed stream 13 would probably be mixed here. No matter which system is used, the material leaving the mixer 17 than would pass on a travelling belt 19 underneath a plow 20 which would level the top of stream 21 to a constant height above the belt 19. The leveled material 21 would then pass between the source 23 and the detector 25 before going to the (not shown) pelletizing apparatus or to the sintering machine. When it is necessary to hold a point at or very near the bottom of a curve such as that shown in FIGURE 4, which is the case when the mix is to be balled, the signal from the detector 25 would go to the computer means 24 which obtains an amperage signal from the ionization detector 25 and stores this value in its memory. It then sends a signal to a water-flow controller 39 which adjusts valve 26, thus changing the water rate at spray head 15 by a small amount. A new signal from the ionization chamber 25 then enters the computer 24. This signal is compared in the computer with the previous ones. Since the detector advantageously contains a compensating back E.M.F., as hereinafter explained, the resultant amperage output from the detector decreases when the decreased bulk density allows more

5

gamma rays to pass through the bed. If the amperage reading in computer 24 is higher, it changes the water rate at valves 26, 15, in the opposite direction from the previous change by resetting the flow controller 39; if lower, it changes the water rate in the same direction. Thus, by continual trial and error, it finds and holds the minimum point on the curve.

A system of this type, method (1), with a computer in the circuit which has been preset to hold automatically the minimum point on a curve such as that shown in FIGURE 4 or which can be preset with a bias that will automatically hold a point near the minimum for such a curve is most satisfactory since it will maintain the best moisture for balling regardless of changes in the actual curve due to changes in the constituents of the mix or due to changes in the size characteristics of the particles that make up the mix.

However, when it is desired to hold a moisture content which falls somewhere on the curve which is considerably short of the minimum point, a second method (2) is employed in which the computer can be omitted from the circuit and a simple controller 39 can be used, which holds a constant amperage input from the radiation detector by regulating the water valve 26. This is usually the case when the mix is merely to be fluffed up rather than balled in order to obtain a good bed permeability when it is placed on the sinter machine. Such a method (2) of control is satisfactory when the relationship between moisture content and bulk density is well defined and when the bulk density corresponding to the desired moisture content is well above the minimum. If a pelletizing apparatus is not to be used, the moisture content required to give maximum bed permeability would probably be somewhere in this portion of the curve. If, however, the optimum moisture region is near the bottom of the curve, the simple control instrument 24 would erroneously call for more water if the moisture content of the material being measured were actually on the upturned portion of the curve beyond the minimum point. Either a computer, or the system to be next described, would then be needed.

A third method which could hold a point at or near the lowest minimum of the curve, provided the curve is well defined and not likely to shift greatly due to changes in composition or the physical characteristics of the mix, is shown in FIGURE 2. This system actually makes measurements at points well above the lowest minimum on the curve and projects to moisture contents equivalent to those at or near the bottom of the curve.

Thus, FIGURE 2 shows a complicated system which will hold the minimum point without the use of a computer. In this case, the material on the belt 11 having been plowed by a plow 27 to a constant level, would pass between a source-detector combination 28, 29. This first unit 28, 29 would, in effect, establish a moisture content from the known moisture versus reading curve for the particular mix 13 being used. The material 13 on the belt 11 would then pass under a water spray 30 which is controlled at 31 to add water at a preset constant rate which is much less than the rate necessary to produce the desired final moisture content. After the water addition at 30, the mixing step 17, followed by the plow 20 is introduced in order to prepare the partially wetted mixture 21 for the second source-detector combination 23, 25 which, in effect, establishes the moisture content set for the material after the intermediate water addition at 30. The signals from the two detectors 29, 25 then pass to a difference relaying mechanism 32, preferably a differential ammeter. The signal from this mechanism 32, being a function of the difference between the moisture content of the mix before adding a measured amount of water at 30 and after adding the measured amount of water at 30 is, therefore, a function of the solids rate on the belt 19. It is transferred by line 38 to a ratio controller 33. Also entering the ratio controller 33 is

6

a signal from a flowmeter 34 on the water line 35 to the second spray 15. This latter signal is converted from the differential pressure across the orifice in meter 34 which is a square-root function of the flow, to a linear function by means of a square-root converter 36 before it enters the ratio controller 33. The ratio controller 33 having one signal 38 linearly proportional to the flow of sinter mix and one signal linearly proportional to the flow of water in the second spray 15, then regulates by line 139 a control valve 37 on line 35 to the second spray 15, to give the correct ratio of water to sinter 21 in order to attain the desired moisture content. A signal from the first measuring device 29 would also go directly by line 40 to the ratio controller 33, in order to reset the base point on the ratio controller 33 when changes in the moisture content of the untreated mix occur.

Such a combination of control instruments will always produce a final mix with the desired moisture content, provided that the reading-versus-moisture curve remains constant. In a large number of cases this would probably be so. Displacements of the curve due, for instance, to small changes in average particle size during normal operation could be adjusted by the operator who would make slight changes in the instrument setting. For large changes in the mix which produce different lowest minimum points on the curves, the operator samples manually and determines the lowest minimum point for that material, and then resets the flow controller 39 for the predetermined minimum bulk density point required, when the computer 24 is omitted from FIGURE 1. The operator does likewise with FIGURE 2, when there is a change in the mix.

Various types of gamma radiation sources may be used in accordance with this invention. These include gamma ray emitting radioisotopes such as cesium 137. Advantageously, the radiation source comprises a 100 mc. pellet of cesium 137. Cesium 137 is preferred because, advantageously, its half life is about 33 years which is sufficiently long so that decay corrections are not burdensome and because cesium has an energy range suitable for this invention. This radiation source 23 produces rays of substantially uniform energy level and of sufficient strength to penetrate through the streams of sinter mix and belt 35 to the detectors so as to produce a signal proportional to the radiation passing through the stream. The radiation source 23 may comprise a container which holds a pellet and is held fixed. Dense metal plates are attached to a frame to shield radiation from the source so as to protect personnel from radiation in the vicinity of the source. The plates also shield stray radiation from impinging on the detector 25. The container has a radiation window comprising a thin piece of aluminum which is substantially transparent to radiation from the pellet. The window is formed as a slot in the container, which is advantageously made of steel, so as to collimate and direct radiation from the pellet, through the stream 21 and belt, to the detector 25 in a substantially concentrated pattern. Conveniently, the radiation is directed through the stream at right angles to the longitudinal axis of the belt.

The detector 25 is located on the opposite side of the stream of sinter mix from the radiation pellet 23 and at a fixed distance from the radiation pellet 23, so as to receive radiation directed through the stream on the belts and to produce an electrical signal corresponding in intensity to the radiation impinging on the detector 25. To this end, the detector may be a Geiger-Mueller counter, an ionization chamber, a scintillation counter, or other similar devices used for measuring radiation. Advantageously, the detector is a cell containing two electrodes that are separated by a filling gas. The cell is a constant voltage generator with variable internal impedances. Like electrolytic cells, the open circuit voltage of the cell is dependent on the nature of the electrodes, and the current produced is a function of the ion concentration. When

the filling gas is forceably ionized by exposure to the radiation impinging thereon, positive ions are attracted to the negative electrode, and negative electrons are attracted to the positive electrode, thus an electrical signal is generated. Advantageously, the detecting cell is the Ohmart cell Model RTS-P measuring cell in a Model CX-1(M) housing made by the Ohmart Corporation, Cincinnati, Ohio.

Gamma radiation from the pellet is attenuated as the radiation passes through the sinter in the sinter stream and this attenuation or absorption is a function of the density of the material in the stream. Since leveling causes the depth of the stream to be substantially constant, the absorption of the gamma rays is a function of the bulk density of the sinter stream. This, in turn, is a function of the moisture content for a given mix. Thus, the detector is exposed to the variable radiation field produced by changes in the bulk density, due to moisture content in the stream of sinter mix.

Advantageously, for accurate measurement a compensating cell is used to provide a null system of measurement. The compensating cell is connected directly in parallel with a measuring cell. Both cells are of the same type except that the compensating cell is opposite in polarity and has a source of radioactivity mounted on a standard screw that projects into a well in the compensating cell. Thus, the position of the source within the compensating cell can be altered and the output current therefrom can be adjusted to the proper value to nullify the output current from the measuring cell when there is no mix on the belt or for any predetermined sample penetrability to gamma radiation.

As an illustration, if it is desired to measure the penetrability to gamma radiation of a sinter mix which varies in bulk density from about 95 pounds per cubic foot to 115 pounds per cubic foot, the measuring cell will generate a substantially constant current when the sinter mix has a substantially constant permeability. For example, the current generated by the cell may be 10 units when the bulk density of the mix is 95 pounds per cubic foot, and 6 units when the bulk density is 115 pounds per cubic foot. The compensating cell is adjusted to generate a current of minus 10 units and the measuring cell current of plus 10 units add algebraically to produce zero current for a bulk density of 95 pounds per cubic foot. When the bulk density of a sinter mix is 105 pounds per cubic foot, the measuring cells produce plus 6 units while the compensating cell is still producing minus 10 units; thus, a net current of four negative units results for a bulk density of 115 pounds per cubic foot. When the control unit 23, 25 is arranged with a computer 24 (FIGURE 1) which continually adjusts to hold the point of lowest minimum bulk density, the compensating cell would be set to generate a current which is greater than that expected from the measuring cell at the lowest minimum bulk density, so that the resultant current would never become as low as zero.

The invention as hereinabove set forth is embodied in particular forms and manners, but may be variously embodied within the scope of the claims as hereinafter made.

What is claimed is:

1. The method of regulating and controlling the amount of moisture in a feed sinter mix which is to be balled before sintering so as to provide minimum bulk density thereby providing for maximum permeability of air through the mix on a sinter bed, comprising:

(a) automatically adding water to the feed mix to form a moistened mix, said water being added in an amount

to adjust the balling characteristics of the material of the mix to the optimum value for balling, which value just the balling characteristics of the material of the mix to the optimum value for balling, which value is a region of minimum bulk density at which the bulk density stops decreasing as a function of the water content;

- (b) passing gamma rays of radiation of predetermined strength through the moistened mix;
- (c) automatically detecting the amount of radiation received, which amount of radiation is indicative of the actual water content of the moistened mix;
- (d) automatically comparing the radiation received through the moistened mix to that received through a mix which has the correct water content to give it the aforesaid minimum bulk density to determine the difference between the actual water content of the moistened mix and the desired water content; and
- (e) automatically adjusting valve means for the flow of water to the feed mix as aforesaid, by and in accordance with the difference between the received radiation value at said minimum bulk density and the value of the radiation received through the moistened mix, to increase or decrease as governed by computer means the flow of water automatically in amount to attain constantly a value of radiation indicative of the region of said minimum bulk density.

2. Apparatus for regulating and controlling the amount of moisture in a feed sinter mix which is to be balled before sintering, comprising:

- (a) means for automatically adding water to the feed mix to form a moistened mix, said water being added in an amount to adjust the balling characteristics of the material of the feed mix to the optimum value for balling, which value is a region of minimum bulk density at which the bulk density stops decreasing as a function of the water content;
- (b) means for passing gamma rays of radiation of predetermined strength through the moistened mix;
- (c) means for automatically detecting the amount of radiation received which amount of radiation is indicative of the actual moisture content of the moistened mix;
- (d) means for automatically comparing the amount of radiation received, in relation to those received through a mix which has the correct water content to give it the aforesaid minimum bulk density, to determine the difference between the actual moisture content of the moistened mix and the desired moisture content;
- (e) means for automatically adjusting valve means for the flow of water to the mix by and in accordance with the automatically measured difference between the received radiation value at said minimum bulk density and the value of the radiation received, to increase or decrease as governed by computer means the flow of water automatically in amount to attain constantly a value of radiation indicative of the region of said minimum bulk density.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,148,971

September 15, 1964

Somerled Macdonald 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 8, lines 2 to 4, strike out "which value just the balling characteristics of the material of the mix to the optimum value for balling,".

Signed and sealed this 5th day of April 1966.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents