March 4, 1952 R. R. BERRY 2,587,686

ORE SORTING SYSTEM

Filed April 27, 1948 5 Sheets-Sheet 1

Fig. 1.

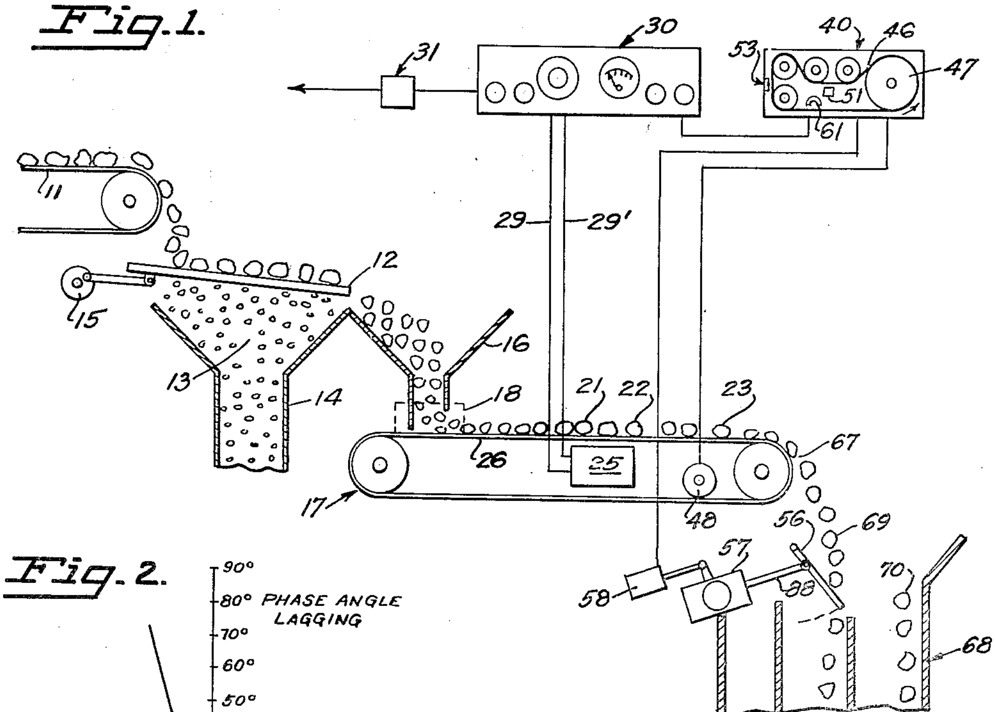


Fig. 2.

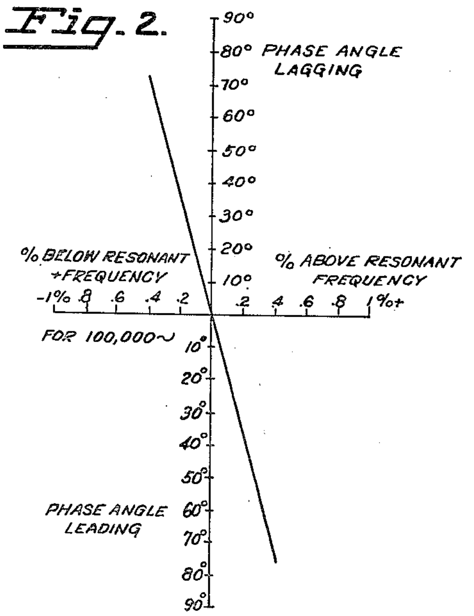


Fig. 4.

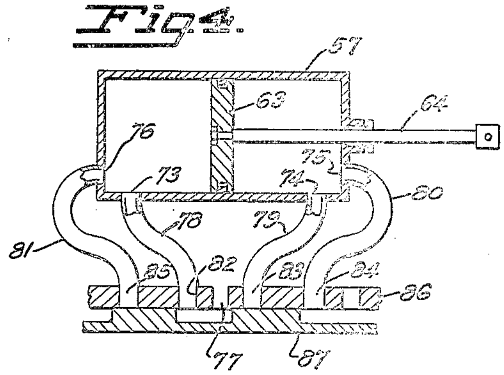
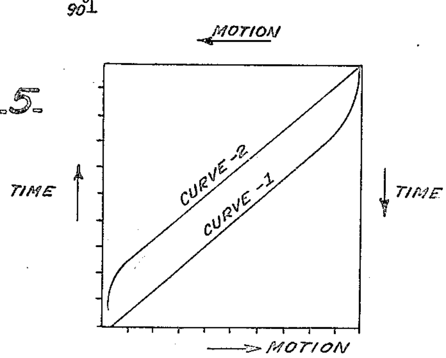


Fig. 5.



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ORE SORTING SYSTEM

Filed April 27, 1948 5 Sheets-Sheet 2

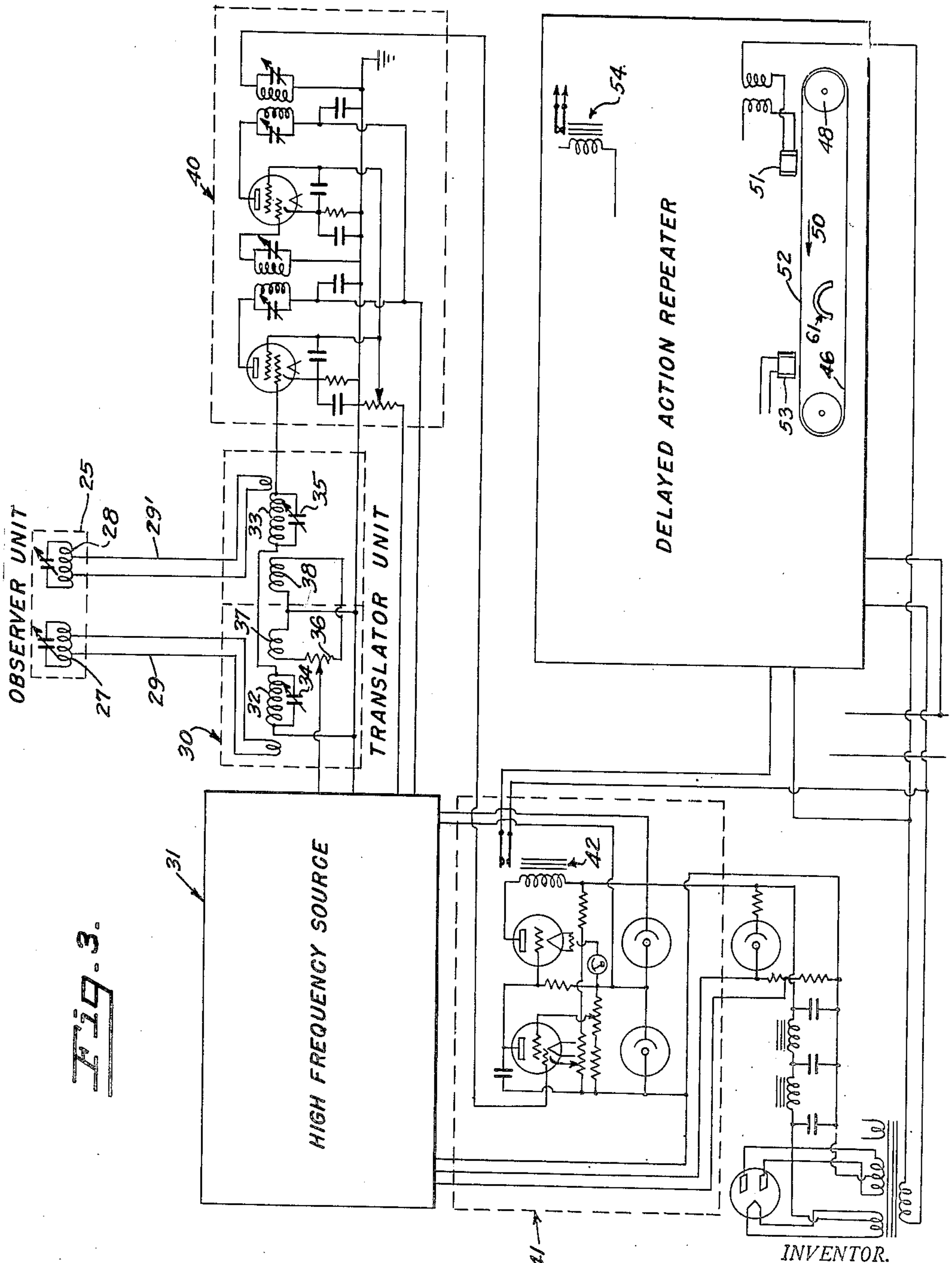

Fig. 3.

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Fig. 6.

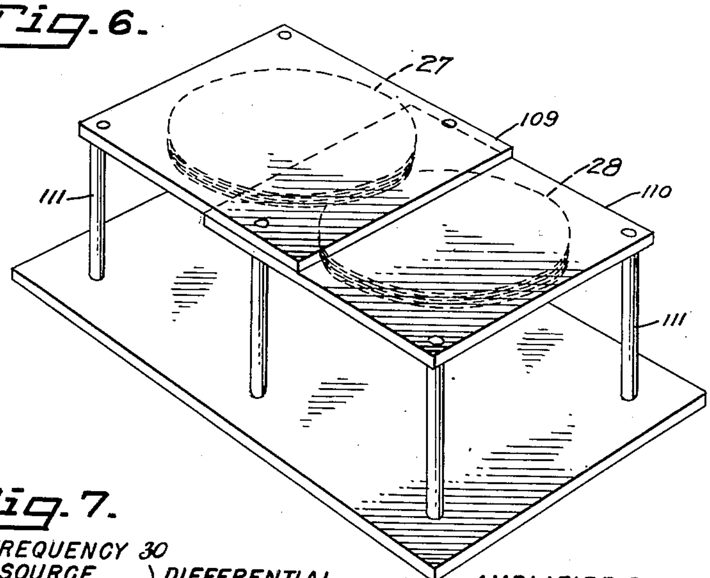
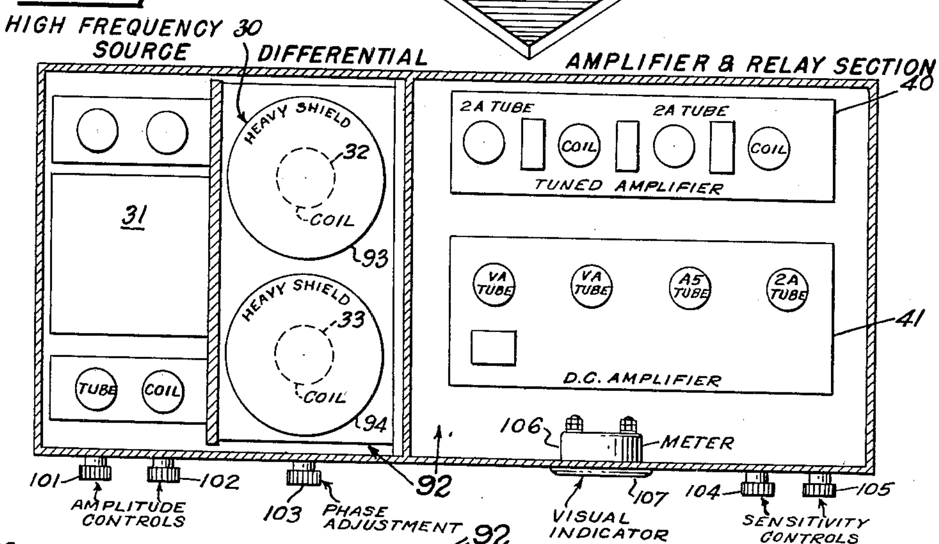


Fig. 7.



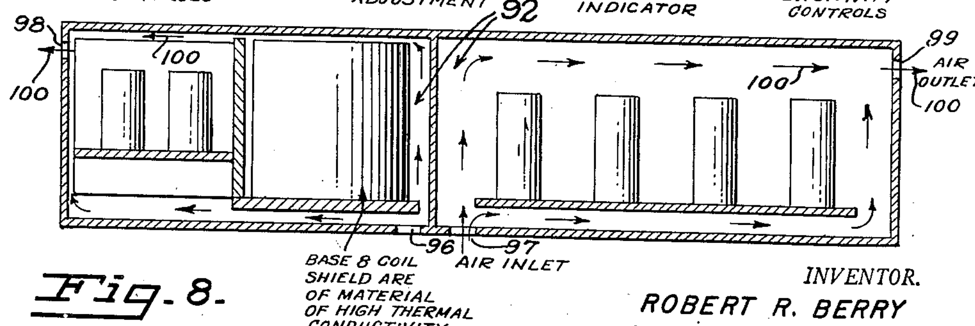


Fig. 8.

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Fig. 9.

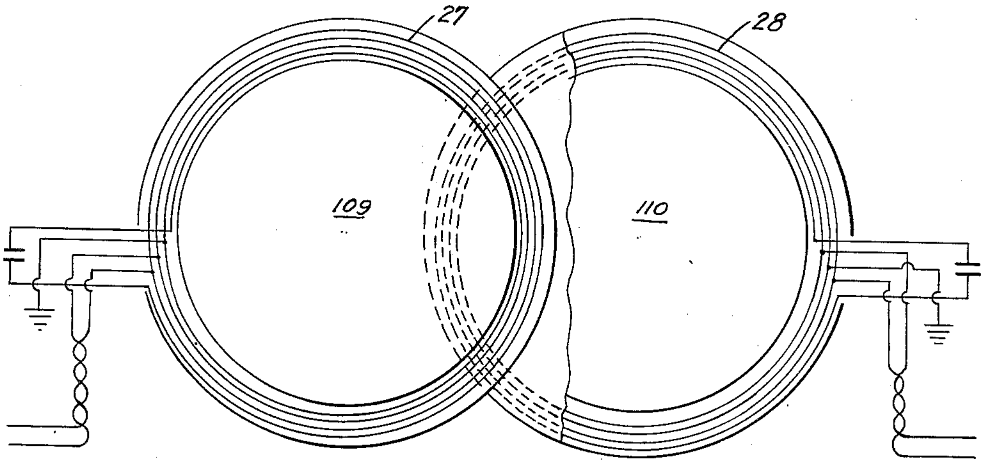
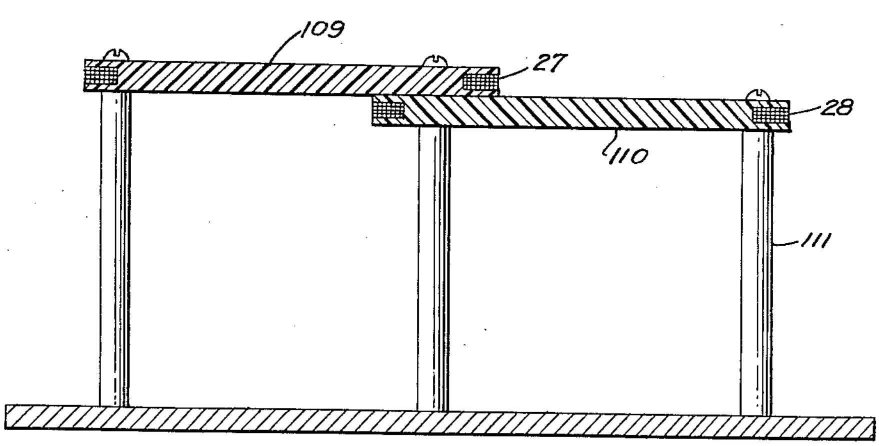


Fig. 10.



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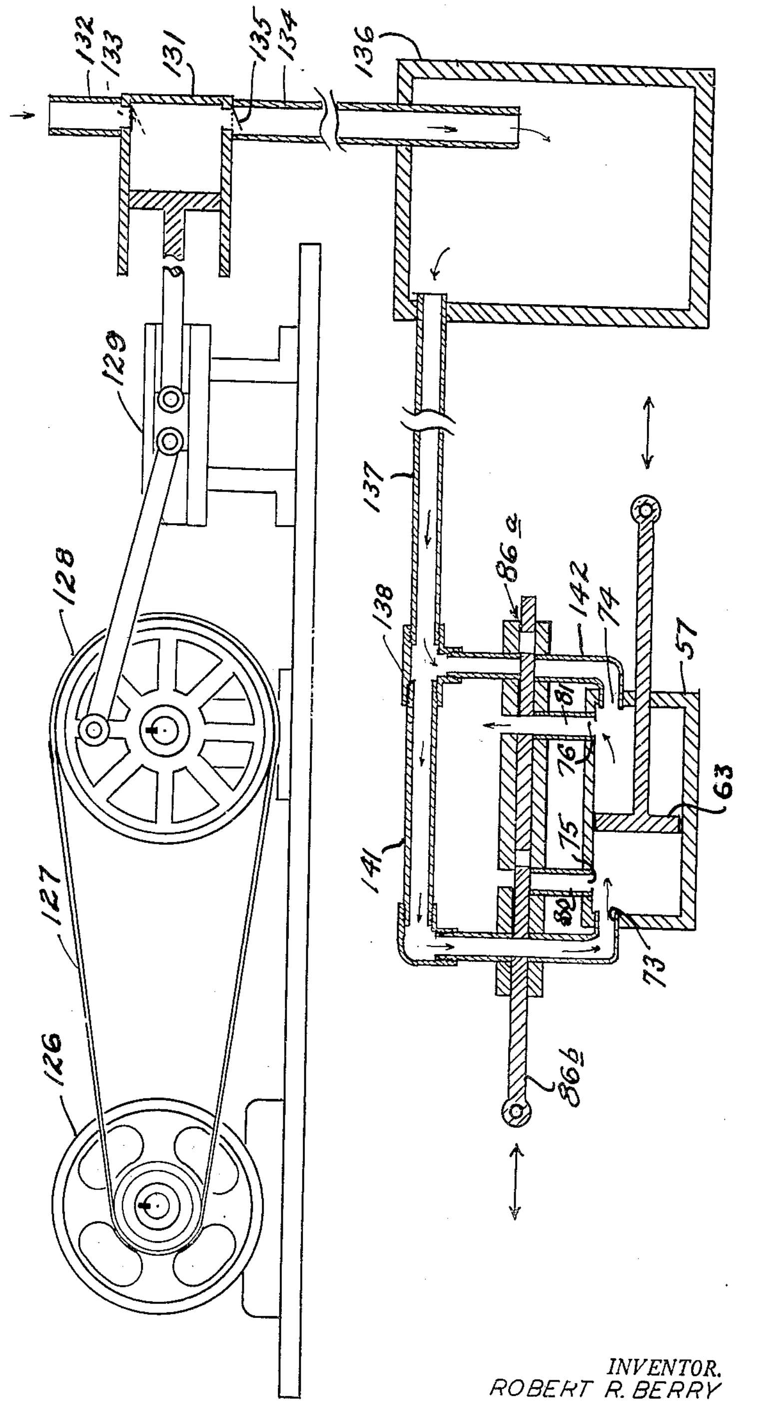

Fig-11

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UNITED STATES PATENT OFFICE

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ORE SORTING SYSTEM

Robert R. Berry, San Francisco, Calif.

Application April 27, 1948, Serial No. 23,561

1 Claim. (Cl. 209—81)

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The invention, in general, relates to means for recovering values from mineral deposits, and more particularly relates to an improved electro-mechanical system affording high speed and efficaceous separation or sorting of values-bearing substances from waste materials under all conditions of mining operations.

Heretofore, the grading or sorting of mine rock has been carried out mainly either by hand sorting or by the utilization of vibratory devices combined with electrical means. In hand sorting, it has been common practice to make use of a conveyer belt for carrying variable sizes and character of mine rock past a group of operators or sorters who hand pick waste material and over-sized rocks from the value-bearing material in order thus to grade the ore prior to delivery to concentrating tables or devices. It has been found that the cost of hand sorting is so prohibitive as well as inefficient because predicated solely on visual inspection that this method is somewhat restricted. The handling and grading or sorting of mine rock by electrical means heretofore practiced has presented serious and numerous complications principally because of the heterogeneous nature of the materials being handled and also the inherent difficulties or factors encountered and normally present in mining operations, such as variations in temperature, moisture and vibration. Other inherent difficulties include installation problems under variable conditions at different mining locations or regions, and other handling techniques common to mining and milling. It may be observed that because of the above mentioned complex problems, sorting methods heretofore worked out for packaged products and articles of determinate or certain sizes and shapes are not suitable for mining, especially the sorting of the mine rock. The present invention is directed to the provision of an electro-mechanical combination or system which obviates the foregoing difficulties and disadvantages of prior systems and methods, as well as which affords a low cost method to effect ore concentration.

A primary object of my invention is to provide an improved ore sorting system containing electro-mechanical means which utilizes the high frequency power factor of the mine rock or mineral materials as the bases for controlling and effecting the physical separation or sorting.

Another important object of the present invention is to provide an improved ore sorting system of the indicated nature which is additionally characterized by its simplicity, its low cost of in-

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stallation and maintenance, its highly efficaceous performance, and its flexibility or adaptability to all mining conditions however severe and abnormal.

A still further object of the invention is to provide an improved ore sorting system for the ready separation of ores and of the aforementioned character, which is readily adaptable to mining equipment already installed and without material modification of such installed equipment.

Another important object of my invention is to provide a system of the indicated nature which increases the speed of handling ore as well as the yield of values therefrom, without restricting its effectiveness of performance.

Other objects of the invention, together with some of the advantageous features thereof, will appear from the following description of a preferred embodiment of the invention which is illustrated in the accompanying drawings. It is to be understood that I am not to be limited to the precise embodiment shown, nor to the precise arrangement of the various parts, as my invention, as defined in the appended claim, can be embodied in a plurality and variety of forms.

Referring to the drawings:

Fig. 1 is a diagrammatic flow sheet depicting a preferred embodiment of the invention.

Fig. 2 is an enlarged graph representing the phase shift curve of a resonant circuit, which is variable depending upon the particular materials handled and the frequency of the alternating current supplied, exemplifying the amount of phase angle displacement between eddy currents resulting from the introduction and presence of an alternating electro-magnetic field in a given material, and the currents producing the field.

Fig. 3 is a diagrammatic view of the various electrical elements employed in the preferred embodiment of the invention.

Fig. 4 is an elevational sectional view of an electrically controlled air cylinder employed in the preferred embodiment of the invention.

Fig. 5 is a graph exemplifying optimum performance curves for the air cylinder depicted in Fig. 4.

Fig. 6 is a perspective view of a remote observer unit, with cover removed, employed in the preferred embodiment of the invention; this view illustrating the manner of mounting the coils of the unit.

Fig. 7 is a longitudinal sectional view as well as diagrammatic view of the electrical translator unit employed in a preferred embodiment of the invention.

Fig. 8 is an elevational sectional view of the unit shown in Fig. 7, with arrow indicators to show air flow in, through and out of the unit.

Fig. 9 is an enlarged plan view of the overlapping coils of the observer unit depicted in Fig. 6, together with a diagrammatic showing of electrical connections for the coils.

Fig. 10 is an elevational sectional view of the unit illustrated in Fig. 6.

Fig. 11 is a diagrammatic view of the fluid control system.

In its preferred form, the improved ore sorting system of my invention preferably comprises means for continuously moving pieces of mine rock through compound differential electrical fields which are specially balanced and created by the operation of tuned, high-frequency alternating current circuits, a differential circuit coupled to said alternating current circuits; said differential circuit operating at the same frequency as said alternating current circuits and the voltage developed by said differential circuit varying in response to the varying electrical characteristics of different pieces of mine rock passing through said field, together with means responsive electrically to differences in voltages developed by said differential circuit for mechanically separating out recurrently and at predetermined times individual pieces of mine rock of determined electrical characteristics.

At the left side of Fig. 1 of the annexed drawings I have shown schematically various equipment common to mining operations including a primary conveyer 11 for moving mine rock from ore bins and primary crusher, not shown, to a vibratory screen 12 which effects the screening of "fines" 13 into a hopper 14 without sorting. A motor-driven eccentric unit 15 affords requisite means for vibrating the screen 12, which is common practice. Mine rock of approximately 1½ inches in cross-section, and greater, passes over the vibratory screen 12 and into a hopper 16 for delivery to a second conveyer 17, preferably a belt of the endless type; the outlet of the hopper 16 leading to a mechanism, indicated by the dotted block and reference numeral 18, designed to cause the mine rock to be deposited onto the belt 17 either in single pieces approximately 6 inches in cross-section or in six inch piles of smaller 1½ inch cross-section, all in single file, and to be moved in such arrangement thereon, as shown.

In accordance with my invention, the individual pieces or piles of mine rock, designated by the reference numerals 21, 22 and 23, generally, are caused to pass through compound differential electrical fields created by the operation of tuned, high-frequency alternating current circuits. In Fig. 1 I have illustrated the electrical unit which creates the aforesaid fields, in block diagram and designated by the reference numeral 25, and such unit is located beneath the upper run 26 of the conveyer 17 approximately at the longitudinal center thereof. As illustrated in Figs. 3, 6, 9 and 10 of the accompanying drawings, the observer unit 25 comprises two tuned circuits including coils 27 and 28 which preferably are wound radially in the form of "pancakes" and so mounted that the axis of each coil is parallel to that of the other coil with the windings overlapping one another, for reasons to be hereinafter explained, to effect zero electromagnetic coupling of the coils.

As particularly illustrated in Figs. 1 and 3, the

two coils 27 and 28 of the observer unit 25 are individually coupled by means of separate transmission lines 29 and 29′ to a translator unit which is shown in dotted block diagram and designated by the reference numeral 30. The arrangement is such that all of the resonant circuits involved in the observer and translator units are adjusted to one and the same frequency, which is that of the high-frequency alternating current source depicted in Fig. 3 in full line block diagram and designated by the reference numeral 31. The elements of the high-frequency alternating current source 31 are conventional and, therefore, are not shown in detail in the drawings.

With particular reference to the translator unit 30, it is to be observed that it is comprised of two separate resonant circuits consisting of secondary coils 32 and 33, together with capacitors 34 and 35, respectively, said circuits being differentially coupled to the high-frequency source by means of primary coils 37 and 38. It is to be noted that no common coupling exists between these resonant circuits. A resistor 36 in the circuits functions to control the relative amplitudes of the circulating currents in the aforesaid branches of the differential circuit of the translator unit 30. Preferably, the components of the differential circuit are mounted in separate compartments of the translator unit and are energized individually or separately from the high-frequency source 31, as illustrated in Fig. 3 of the drawings.

The two resonant elements of the translator unit 30 are so energized that the circulating currents establish voltages in phase opposition which are fed, by means of a series of connections, to an amplifier which is depicted generally in dotted block diagram at the right of Fig. 3 and designated generally by the reference numeral 40.

Under operating conditions, without having any foreign object introduced into the field of the observer unit 25, the phase relationship within the differential circuit of the translator unit is such that no signal voltage appears at the input of the amplifier 40. The presence of a foreign object of certain electrical characteristics in the field of the observer unit 25, however, will reflect electrically through the transmission lines 29, 29′ and the differential circuit of the translator 30, such as the introduction by means of conveyer 17 of a succession of individual pieces or piles of mine rock 21, 22, and 23 continuously through the field created by the high-frequency alternating current and the elements of the observer unit 25.

My improved system is effective with respect to both good electrical conductive material and relatively poor electrical conductive material. In the case of mine rock of good electrical conductivity, the eddy currents which result from the presence of an alternating electro-magnetic field are in phase with the currents producing such field, and the power factor of the rock approaches unity representing a low-loss condition so that under my improved system such mine rock of near unity power factor is readily sortable from other mine rock of different power factor as the rock passes through the field of the observer unit 25. This operation is a function of the de-tuning effect of the circuit elements of the observer unit by a foreign object that has good electrical conductivity, although effective ore separation does not depend upon de-tuning. On the other hand, in the case of mine rock of relatively poor electrical conductivity, the eddy currents resulting from passing of such type of mine rock through the field of the observer unit 25 are out of phase with the currents producing such field and the power factor of the rock is less than unity, representing a condition of some loss. In short, mine rock materials having certain assemblages of elements will support eddy currents having characteristic power factors in specific relationship to the produced field of the observer unit 25 through which the mine rock is passed. It is obvious, therefore, that the magnitude of the loss due to the power factor depends upon the nature of the rock material and the frequency of the alternating current employed to produce the initial field. The essence of the present invention resides in taking advantage of this high-frequency distinction between types of rock by utilizing one of the properties of the electrically resonant or tuned circuit; namely, that portion of the phase shift curve which lies between plus or minus 1% of the preferred resonant frequency. Thus, it is possible to distinguish and effect mechanical separation of rocks because of their difference in electrical conductivity. In Fig. 2 of the annexed drawings, I have shown the phase shift curve for a tuned circuit having a "Q" factor of 450 and a resonant frequency of 100,000 cycles. By "Q" factor is meant the ratio of the reactance to the high-frequency resistance of a tuned circuit (i. e., ratio of energy stored to energy dissipated per cycle) and such factor, therefore, is a figure of merit of a circuit; the high frequency resistance being the sum total of all the losses inherent in the tuned circuit plus the losses reflected from a foreign object, such as mine rock coming through the field of the inductive component. Hence, if an object of high power factor comes within the field of the observer unit 25, the "Q" factor is lowered and the slope of the phase shift curve is changed; a result of the increase in circuit losses produced by the introduction of such object, and the change in "Q" factor is transmitted as a change in load through transmission lines 29 and 29′ to the other circuits above described which are adjusted to the same resonant frequency as that of the observer unit 25. It may also be noted that the introduction of loss into the differential circuit, or change in load through the aforesaid transmission lines, by the presence of mine rock of low electrical conductivity in the observer unit field, not only brings about a variable change in the slope of the phase shift curve but a variable change in the voltage developed by the differential circuit. This difference in voltage is amplified sufficiently, by means of conventional amplifier means, illustrated at the lower left of Fig. 3 of the drawings and designated generally by the reference numeral 41, to cause the operation of a relay 42 in the translator circuit 30.

In order to preserve the function of the differential circuit, no common coupling can exist between the resonant elements of the differential circuit. Insofar as the coils 27 and 28 of the observer unit 25 are coupled individually to their separate resonant elements in the differential circuit, it can be seen that any coupling between the coils of the observer unit 25 would be reflected as coupling between the resonant elements, thus destroying the initial premise. Therefore, it becomes necessary to adjust the coils of the observer unit 25 so that zero coupling results between the two coils 27 and 28. The described technique of overlapping the coils 27 and 28 in the observer unit 25 is designed primarily to result in zero coupling while maintaining circuit symmetry. In addition, the presence of the two overlapping coils is for the purpose of stabilizing the entire differential unit with respect to temperature, vibration and external electrical influences.

In accordance with my present invention, means are provided for re-currently recording the response of the system to the electrical characteristics of individual pieces or lumps of mine rock passing through the field of the observer unit 25, and re-currently reproducing or picking up the recorded responses for controlling at predetermined times a mechanical separator whereby desired mine rock is separated out from waste or non-value mine rock. These means include an endless steel belt 46 which is driven from the conveyer belt 17 by a set of self-synchronizing motors 47 and 48 which are commercially available under the trade-mark "Selsyn"; the steel belt 46 and the selsyn motors being schematically illustrated in the lower right of Fig. 3 of the annexed drawings, and the direction of travel of such steel belt 46 being indicated by the arrow 50. In addition to the foregoing, the aforesaid means includes a recorder head 51 mounted above but in close proximity to the upper run 52 of the steel belt 46 and in electrical connection with the relay 42 of the differential circuit of translator unit 30, for actuation by relay 42, and resulting in the delineation of the responses of the system to the electrical characteristics of the mine rock passing on the upper run of conveyer belt 17 at the location of the observer unit; such delineations being upon the moving endless steel belt 46 and such electrical characteristics of certain mine rock that affect the voltage in the differential circuit of the translator unit 30 being the only responses of the system that will be relayed to the recorder head 51 for delineation on the belt 46. Such recordation and pick-up or reproducing means also include a pick-up unit 53 mounted above but in close proximity to the upper run 52 of belt 46 and at a predetermined distance from the recorder head 51, as illustrated in Fig. 3 of the drawings, thus affording a lapse of time between the time of recordation of the response of each individual piece or lump of mine rock having certain power factor characteristics to effect the aforesaid voltage variation, and the time of reproducing or picking up the response as delineated on the steel wire belt 46. It is to be understood that since both the conveyer belt 17 and the steel wire belt 46 are continuous and operated in synchronism by the self-synchronous motors 47 and 48, the recordation and reproduction of the responses of the system to the electrical characteristics of the different individual pieces or lumps of mine rock 21, 22 and 23 is continuous and re-current while the system is in operation. The pick-up or recording unit 53 functions to control and is in electrical connection with a relay 54 which, in turn, controls the operation of a separator gate 56 through a cylinder 57, the piston of which is controlled by a solenoid 58 actuated directly from relay 54. The synchronous motors 47 and 48 effect the exact timing of the mechanical separation of value bearing mine rock from the waste or non-value rock. Conventional amplifier means, not shown, are interposed in the circuit containing the pick-up or reproducing unit 53 and the relay 54 for effective operation of the solenoid 58 through the relay 54. In order that the recorder unit 51 and the pick-up or reproducing head 53 be effective for their recurrent operations, I provide a magnetic eraser 61 for clearing any electrical response character delineations applied to the steel wire 46 on each complete run of the belt 46, and prior to the time the recorder unit 51 operates.

As particularly illustrated in Figs. 1 and 4 of the accompanying drawings, the solenoid 58 is arranged with the air cylinder 57 for covering and uncovering the ports of the cylinder in which the piston 63 reciprocates as air is admitted from a source of air supply, not shown, first to one side and then the other side of the piston. The piston rod 64 of piston 63 carries a pivotally mounted gate 56 on its exposed end which is adapted to swing into and out of the path of the falling mine rock that drops off the end or terminus 67 of the endless conveyer 17. A suitable multiple channel hopper 68 is arranged beneath the gate 56 to receive in its different channels both the waste material 69 and the separated out value-bearing mine rock 70; the latter being deflected by the gate 56 as the gate responds to the movement of the piston 63 of the air cylinder.

For optimum operation and minimum wear, the motion of the piston 63 of the air cylinder 57 should follow the curves depicted in Fig. 5 of the annexed drawings so that in one direction the piston should follow curve 1 and in the reverse direction should follow curve 2. In other words, the piston 63 should slow down toward the end of its stroke and this is accomplished either with the arrangement illustrated in Fig. 4 or the arrangement illustrated in Fig. 11 of the annexed drawings, and by shaping the ports 73, 74, 75 and 76 of the cylinder 57, which are in communication with ducts 78, 79, 80 and 81, respectively, as indicated in Fig. 4, leading from ports 82, 83, 84 and 85, respectively, in valve head 86. It may be added that ports 73 and 74 of the air cylinder 57 are so placed that they are closed by the piston 63 at the ends of its stroke to effect a shock absorbing action as well as controlling exhaust opening 77 in valve head 86. In the arrangement in Fig. 11 of the drawings there are illustrated a typical mine compressor arrangement including a motor 126 with belt drive 127 to the fly wheel 128 of a compressor unit 129. In this arrangement, an air head 131 is provided for supplying air through air inlet 132 controlled by check valve 133 and the supply of air from the compressor is delivered from air head 131 to an outlet conduit 135 which also is controlled by a check valve 134. The supplied air preferably is stored in a reservoir 136 from which it is delivered through a conduit 137 to a T-coupling 138 for diverting the air flow through conduits 141 and 142 to the ports 73 and 74, respectively, of the air cylinder 57 within which is reciprocated the piston 63. As in the prior described arrangement, the air cylinder ports 75 and 76 communicate with ducts 80 and 81, respectively, leading to a valve head 86*a* which is controlled by a slider valve 86*b*. By the foregoing arrangements gate 56 is operated with the least amount of time as considerable power is applied thereto to overcome the inertia of the mechanical elements.

In Figs. 7 and 8 of the accompanying drawings, I have illustrated a preferred construction of cabinet 91 for housing not only the equipment and circuits of the high-frequency alternating

current source 31 but also the units of the differential circuit constituting the translator unit 30, together with the tuned amplifier circuit 40, the D. C. amplifier 41 and the relay 42 of the translator unit. The two coils of the differential circuit conveniently are housed in formed compartments 92 of the cabinet and shielded by heavy shields 93 and 94 which, together with a base 95 all formed of material of high thermal conductivity, afford optimum mounting of the differential circuit units. The cabinet is maintained at desirable temperature by providing suitable air circulation throughout the various compartments and to this end the front and end walls of the cabinet 91 are formed with air inlets 96 and 97, and air outlets 98 and 99, respectively. The direction of air flow through the compartments of the cabinet is indicated by the arrows 100. The high-frequency alternating current source 31 is provided with two amplitude controls, actuated by knobs 101 and 102 on the exterior front of the cabinet; the phase adjustment of the translator unit and circuits is controlled through a knob 103 extending at the front of the cabinet, and the amplifiers are controlled for sensitivity by hand-knobs 104 and 105 also extending at the front of the cabinet. A suitable meter 106 is installed in the compartment containing the amplifiers and furnishes, through a window 107 at the front of the cabinet, visual indication of the status of such amplifiers at a given moment. In Figs. 6 and 10 of the annexed drawings, I have shown preferred mounting of the over-lapping coils 27 and 28 of the observer unit, such mounting being effected by two overlapping plates 109 and 110 supported on standards 111.

The foregoing described ore sorting system effects continuous storing of electrical information as to the electrical characteristics of individual pieces of mine rock as such pieces are continuously moved by the conveyer 17 through an induction field produced by the high-frequency alternating current source 31 through observer unit 25 located beneath the upper run of the conveyer at a predetermined point, and such stored information is repeated at a delayed and/or proper time through the recorder unit 51 and reproducer or pick-up unit 53 operating on the endless steel wire 46 and thus effecting the mechanical separation of value bearing mine rock from the waste or non-value bearing material at a point remote from the observer unit 25. A symmetrical electrical system is effectively maintained by the use of the two over-lapping coils 27 and 28 of the observer unit, and the separate transmission lines 29 and 29′ leading to the differential circuit of the translator unit 30, thus preventing temperature variations and frequency drift from disturbing the balance of the system. From Fig. 2 of the drawings, it can be seen that within the region of plus or minus 1% of the preferred resonant frequency, the phase shift curve is a straight line, which means that a frequency variation of plus or minus 1% will not disturb a circuit sensitive to .001% or 8% of 1° phase change. Also, the opposed phasing of the overlapping coils 27 and 28 renders the system impervious to outside electrical interference without the necessity of shielding and, by the same token, there is no radiation. This cancellation of inductive effect makes possible a multiple installation without interaction between units, even though side by side under the same belt as, for instance, the observer unit 25 and the synchronous motor 48 under the upper run of the conveyer belt 17. An especial feature of the present invention resides in the recorder, reproduction and eraser combination for making impressions and erasing the same from the steel wire 49, thus effecting a time delay in an otherwise substantially continuous operation. As a result, there is accomplished high speed separation of value bearing mine rock from valueless mine rock (when such rock is associated with differences in power factor), all made possible by the combination of the foregoing time delay mechanism together with power operation of the separator gate 58 through controlled air cylinder and pneumatic damping thereof.

It is to be understood that the appended claim is to be accorded a range of equivalents commensurate in scope with the advance made over the prior art.

I claim:

An ore sorting system comprising a high-frequency alternating current circuit, means coupled to said circuit for producing an induction field, a conveyer having a terminal for moving individual pieces of mine rock in single file through said induction field to detect the electrical characteristics thereof, a tuned circuit coupled with said alternating current circuit; said tuned circuit being adapted variably to respond to variations in voltage impressed thereon as a result of electrical characteristics reflected by certain pieces of said mine rock moving through said field, a first relay actuated by said tuned circuit, an endless steel wire, means for moving said steel wire in synchronism with the movement of said conveyer, electro-magnetic recorder means electrically connected with said first relay and mounted in proximity to said wire for impressing and recording on said wire signals or responses to electrical characteristics of certain mine rock reflected in said tuned cir-

cuit and said first relay, an electro-magnet reproducer mounted in proximity to said steel wire but remote from said recorder means for picking up from said wire the electrical responses as recorded thereon by said recorder means, an electrical circuit including said reproducer and a second relay, a multiple-channel hopper mounted below the terminal of said conveyer for receiving said mine rock as it falls by force of gravity from said conveyer at said terminal, an air cylinder mounted adjacent to said hopper, a solenoid for governing the ports of said cylinder, a gate pivotally mounted on the piston rod of the piston of said cylinder; said gate being adapted in one pivoted position to deflect certain of said mine rock from its normal path of fall, and means electrically connected to said second relay for actuating said solenoid to effect reciprocation of the piston of said cylinder and pivoting of said gate on each reproduction of the recorded electrical responses of electrical characteristics of certain of said mine rock reflecting said electrical characteristics into a predetermined channel of said hopper.

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