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2,819,447

SYSTEM FOR DETECTING CONDUCTIVE BODIES

Filed March 27, 1956

2 Sheets-Sheet 1

Fig. 1.

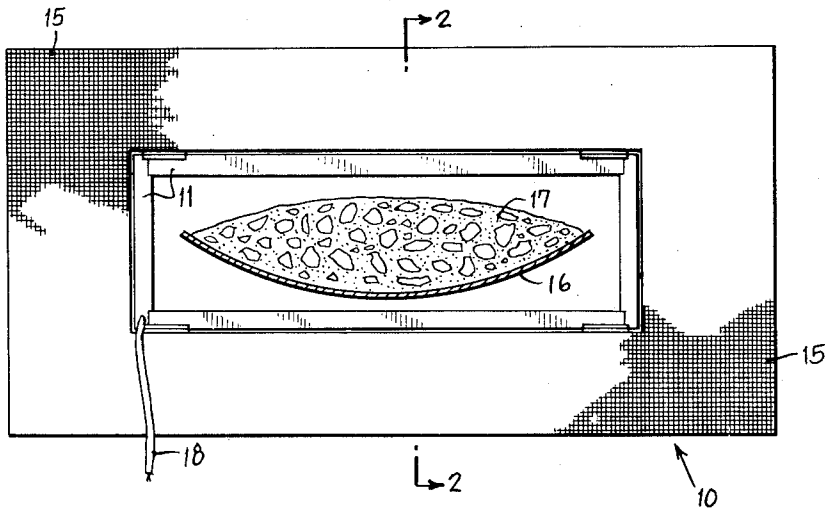
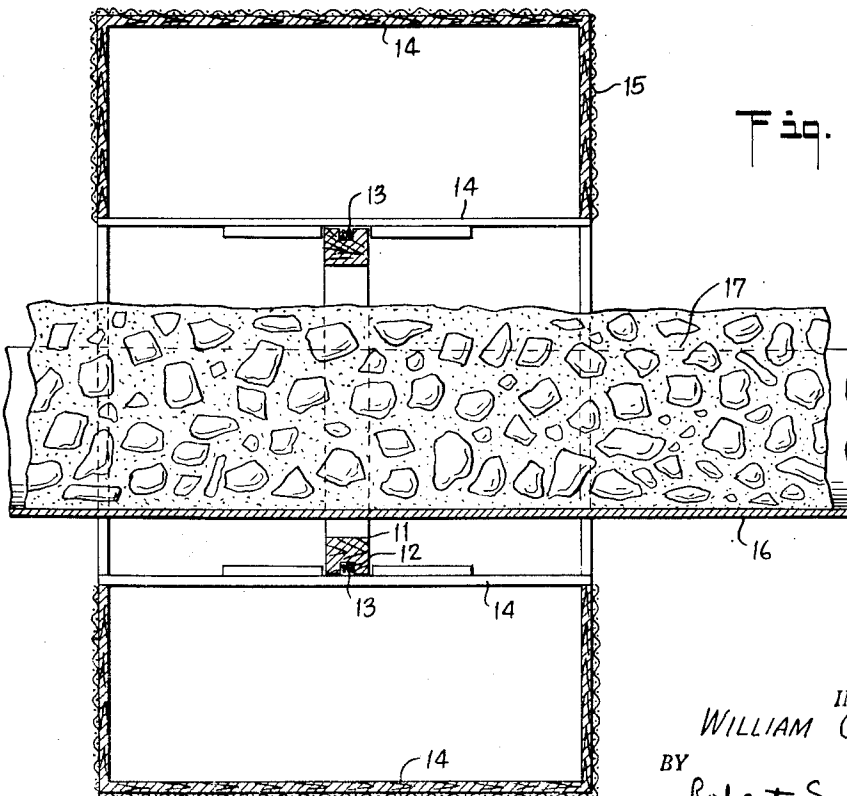


Fig. 2.



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2 Sheets-Sheet 2

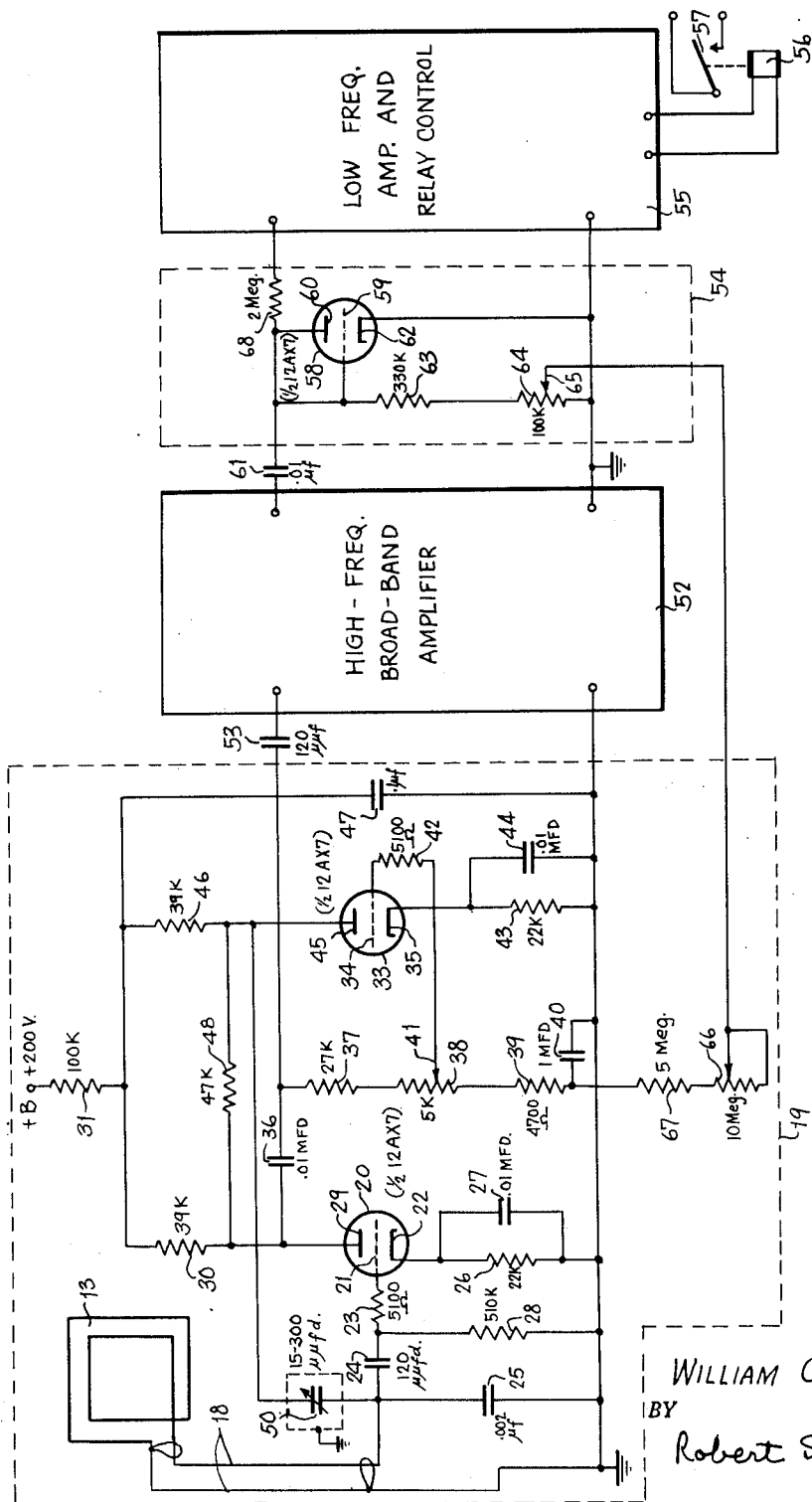


Fig. 3.

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1

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SYSTEM FOR DETECTING CONDUCTIVE BODIES

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18 Claims. (Cl. 324—41)

The present invention relates to systems for detecting conductive bodies in relatively nonconductive magnetic ore and, particularly, to such systems used to indicate the presence of tramp metal in a body of magnetic ore in movement from one point to another.

Relatively large pieces of iron or other metallic substances, commonly referred to as "tramp" metal, may inadvertently be present in ore which it is desired to crush or pulverize by crushing machinery in certain ore concentration processes. Such tramp metal works down into the crusher without breaking up until it stalls the crusher or breaks some part. This results in expensive repairs and lost production, and it is accordingly desirable to detect all such tramp metal in the ore before it has an opportunity to reach the crusher.

The problem of consistently and reliably detecting tramp metal in ore has been an exceedingly troublesome one, and many arrangements have heretofore been proposed in an attempt to provide a satisfactory solution. Magnets and magnetic rolls are in common use to remove stray pieces of magnetic metal from nonmagnetic materials such as coal and the like. It has also been proposed that for the inspection of nonmagnetic materials many forms of exploring inductors be so arranged that magnetic tramp metal shall induce a change in the magnetic flux of the inductor which change is then used to operate an alarm or control a system for rejecting the piece of tramp metal. None of the proposals of this type respond to nonferrous or nonmagnetic material.

In an attempt to detect the presence of both nonmagnetic and magnetic metals, it has been proposed that a system of inductors be used in a bridge arrangement. The inductors are carefully designed and so positioned in balanced relation that there is normally substantially zero inductive coupling between an energized transmitter inductor and an energizable receiver inductor, the inductive balance being upset by a piece of tramp metal in the magnetic field of the inductors. Such unbalance of inductive coupling is then indicated by an appropriate arrangement or is used to operate an alarm or automatic reject control. Excitation of the inductors is usually by a voltage of high audio frequency, and relatively close balance of the inductor system must be maintained to avoid false indications of the presence of tramp metal. In practice, the inductor balancing is found to be so critical that it is usually necessary to rebalance it about once every four hours during operation to counteract drift in spite of all precautions to insure stability.

In an attempt to avoid the relatively critical inductive balance of the arrangement last described, it has been proposed that a tramp metal detector employ a high-frequency oscillator in which an inductor constitutes one element of a resonant circuit determining the frequency of oscillation. This inductor is conventionally constructed with a window through which the material under inspection may be moved, and any tramp metal present in the material then has the effect of changing the resistive and inductive impedance component of the inductor and there-

2

by effecting a change of oscillation amplitude or frequency or both. The detection of the tramp metal may accordingly be based upon change of oscillator frequency or change of oscillation amplitude or both change of frequency and amplitude. When magnetic metal passes through the window of the exploring inductor, the magnetic properties of the metal tend to increase the amplitude of oscillation while eddy currents induced in the tramp metal tend to reduce the amplitude of oscillation. Accordingly there will theoretically be some critical size for a piece of magnetic tramp metal where the two effects last mentioned balance each other and the piece of tramp metal fails to be detected. The same result occurs if the detection is premised upon change of the oscillator frequency. It has been found that if the frequency of oscillation is chosen sufficiently high, of the order of 50 kilocycles or higher, the eddy current losses induced in any solid piece of tramp metal whether magnetic or nonmagnetic outweigh any magnetic effect insofar as changes in amplitude of oscillation are concerned and thus always result in a decrease in the amplitude of oscillation. Operation on these high frequencies, however, requires that all energizing voltages supplied to the oscillatory system be carefully regulated in amplitude and that special precautions be taken to make the equipment relatively immune to changes in system parameters with changes in temperature and humidity. In spite of all such precautions, it has been found in practice that the oscillator amplitude changes slowly over a period of time and this requires resetting of one or more oscillator controls about once every two hours if reasonably reliable and consistent operation is to be effected.

A serious disadvantage and limitation inherent in the oscillatory system last described, particularly in the case of tramp metal detection in magnetic ores such as taconite, is that the finely divided iron oxide particles of the ore create little eddy current loss to reduce the impedance of the exploring inductor whereas the magnetic properties of the ore effect substantial increase of the inductance and impedance of the inductor. This results in increasing the amplitude of oscillation almost in a direct ratio to the incremental volume of ore passing through the window of the exploring inductor, and this effect must be counterbalanced by a sufficiently high operating frequency that the induced eddy current losses in a piece of tramp metal (whether magnetic or nonmagnetic) shall always decrease the amplitude of oscillation sufficient to override the magnetic effect of the iron ore. The ore conventionally is moved on a rubber conveyor belt through the window of the exploring inductor, and if the incremental volume or quantity of ore moving through the inductor was always uniformly the same it would be feasible to adjust the oscillator for operation at a convenient amplitude level with this quantity of ore in the exploring inductor. This is not readily feasible in practice, however, for the reason that the ore on the conveyor belt varies both in quantity and quality (the percentage of iron in the ore). Thus if the oscillator is adjusted to some average value of oscillation amplitude and the quantity or quality of the ore then decreases below the average, the amplitude of oscillation also decreases and provides an indication of the presence of a piece of tramp metal in the ore although no tramp metal is present in fact. Conversely, if the quantity and quality of the ore passing through the exploring inductor increases, the amplitude of oscillation increases above the average and a small or medium size piece of tramp metal may not reduce the amplitude of oscillation to a value below the average and thus fails to be detected.

It is an object of the present invention to provide a new and improved oscillatory system for use in detecting with high sensitivity conductive bodies present in a mov-

ing body of relatively nonconductive magnetic ore, and one which avoids one or more of the disadvantages and limitations of prior proposed tramp metal detecting systems.

It is a further object of the invention to provide a novel oscillatory system characterized by high and consistently reliable transient response to moving conductive bodies of a wide range of sizes and of both magnetic and nonmagnetic materials yet one providing relatively little response, either transient or of longer duration, to a moving body of magnetic ore having widely varying magnetic values by virtue of either the quality or quantity of ore.

It is an additional object of the invention to provide an improved oscillatory system which is relatively free of undesired false response to reactive electrical properties of varying quantities and qualities of moving magnetic ore as well as to long-term changes in system operating parameters while retaining optimum desired transient response to resistive electrical properties of moving conductive bodies even of relatively small size.

It is a further object of the invention to provide a unique oscillation generator of the type having a resonant circuit determining the frequency of oscillation, and including an inductor with a window through which a flow of magnetic ore moves, and one in which the reactive component of impedance of the inductor primarily controls the operating frequency but has insignificant control over the amplitude of oscillation and may vary appreciably with changing quantities and qualities of moving ore whereas the resistive component of impedance of the inductor primarily controls transient oscillation amplitude changes of the system thus to enable a high and stabilized sensitivity of the system to the detection of conductive bodies included in the moving ore.

Other objects and advantages of the invention will appear as the detailed description thereof proceeds in the light of the drawings forming a part of this application and in which:

Fig. 1 illustrates in elevational view, and Fig. 2 in cross-sectional view, the construction of an exploring inductor suitable for use in an oscillatory system embodying the present invention; and

Fig. 3 represents, partly schematically, a tramp metal detecting system embodying an oscillatory system of the present invention in a particular form.

Referring more particularly to Figs. 1 and 2, the exploring inductor assembly 10 comprises a rectangular frame 11 which may be of wood or plastic or the like material having a circumferential groove 12 in which a number of turns of wire are placed to form an inductor 13. The frame 11 with its inductor 13 is fixedly supported within the window of a hollow frame or housing 14 which may be constructed of wood or like material and which has a rectangular doughnut configuration of rectangular cross section as shown. This configuration is merely a convenient one which may be used to support a suitable electromagnetic shield 15 in spaced relation to and surrounding the inductor 13. The shield 15 may conveniently be constructed of small mesh hardware cloth, folded about the housing 14 while preserving the open window of the latter, having all fold laps electrically connected as by the use of solder to provide a continuous electrically conductive shield surface entirely covering the exterior surface of the housing 14 except for its window. The housing construction preferably employs nonconductive fasteners such as wood dowel pins to hold the assembly together although brass screws and brass washers may be used in limited numbers to hold the shield 15 in place on the housing.

By way of example of suitable parameters for a representative exploring inductor, the frame 12 may have a height of 12 inches with a width of 38 inches and the groove 12 may be $\frac{3}{8}$ inch deep and $\frac{3}{8}$ inch wide. The inductor 13 may be wound with 20 turns of #29 enamel

covered wire. The shield 15 may be comprised of $\frac{1}{4}$ inch mesh hardware cloth, and the dimensions of the housing 14 are so selected that the shield 15 is spaced not closer than 8 inches from the inductor 13 at all points.

The exploring inductor and its shield housing are fixedly supported by means not shown in such relation to an ore conveyor belt 16 that the latter extends through the window of the exploring inductor and shield housing. It will be understood that the conveyor belt is supported in conventional manner upon support rollers, not shown, and is suitably driven to move a body of ore 17 at convenient linear velocity through the window of the exploring inductor.

The exploring inductor above described is included as one component of a resonant "tank" circuit of an oscillatory system presently to be described and conveniently positioned a short distance away. The inductor is connected to this oscillatory system through a shielded flexible coaxial cable 18.

The circuit arrangement of the oscillatory system last mention is shown in Fig. 3 as enclosed within a broken line rectangle 19, and includes a triode form of vacuum tube 20 having a control electrode 21 and cathode 22 coupled to the inductor 13 through a grid-current limiting resistor 23 and a coupling condenser 24. A condenser 25 is connected in shunt to the inductor 13 to constitute with the latter a resonant circuit having a resonant frequency of approximately 86,000 cycles per second. The vacuum tube 20 includes a conventional cathode-circuit self-biasing network, comprised by a resistor 26 and parallel-connected condenser 27, which biases the tube to the linear portion of its operating characteristic and the control electrode 21 of this tube is connected to ground through the resistor 23 and a grid-leak resistor 28. The tube 20 includes an anode 29 which is coupled through an anode load resistor 30 and a decoupling resistor 31 to a source of anode potential, indicated as +B.

The oscillatory system 19 also includes a second triode form of vacuum tube 33 having a control electrode 34 and a cathode 35 coupled to the output circuit of the vacuum tube 20 through a condenser 36 and a potential divider which, for energy of oscillatory frequency, is comprised by a resistor 37, a potentiometer 38, a resistor 39 and a condenser 40. A movable contact 41 of the potentiometer 38 is coupled through a grid-current limiting resistor 42 to the control electrode 34 of the tube 33, and the latter includes a cathode-circuit self-bias network comprised by a resistor 43 and shunt connected condenser 44 which biases this tube to the linear portion of its operating characteristic. The tube 33 includes an anode 45 which is coupled to the anode potential source +B through a load resistor 46 and the decoupling resistor 31, the latter being one component of a decoupling network of conventional arrangement including a filter condenser 47 which connects the low potential terminal of the resistor 31 to ground. A degenerative energy-feed back resistor 48 couples the anode 45 of the tube 33 and the anode 29 of the tube 20 to improve in well known manner the stability and linearity of the operating characteristics of the tubes 20 and 33 which, with their associated circuit components, essentially comprise a tandem arranged two stage resistance coupled amplifier. To cause the system just described to generate sustained oscillations, the output circuit of the vacuum tube 33 is coupled through an adjustable condenser 50 to the input circuit of the vacuum tube 20.

The oscillatory system 19 is included in a tramp metal detector which, as shown in Fig. 3, includes a conventional high-frequency broad-band amplifier 52 coupled through a condenser 53 and the condenser 36 to the output circuit of the vacuum tube 20, an amplitude demodulator 54 coupled to the output circuit of the amplifier 52, and a conventional low-frequency amplifier and relay control system 55 which is coupled to the output circuit

of the demodulator 54 and includes in its output circuit a suitable relay 56 having contacts 57 used to control a suitable tramp metal alarm or tramp metal reject system not shown. The broad-band amplifier 52 has a broad pass-band characteristic approximately centered about the nominal oscillatory frequency (86 kilocycles per second) of the oscillatory system 19, and to this end may be comprised by a single-stage resistance coupled amplifier with broad-band translation characteristic. The demodulator 54 includes a triode form of vacuum tube 58 operated as a diode rectifier by having its control electrode 59 and anode 60 connected together and coupled through a condenser 61 to the output circuit of the amplifier 52. The cathode 62 of the tube 60 is connected to ground, and the demodulator includes a load resistor comprising a fixed resistor 63 in series with a potentiometer 64. The movable contact 65 of the potentiometer is coupled through an adjustable resistor 66 and a resistor 67, comprising elements of a filter network which includes the condenser 40, to the junction of the voltage divider resistor 39 and bypass condenser 40. A filter resistor 68 couples the demodulator 54 to the low-frequency amplifier and relay control unit 55, which is of conventional arrangement and may have the general construction shown in the Harmon et al. United States Patent 2,660,704.

Considering now in greater detail the operation of the oscillatory system 19, oscillations appearing in the resonant circuit comprised by the inductor 13 and condenser 25 are amplified by the vacuum tubes 20 and 33 and the amplified oscillations are fed back through the feed-back condenser 50 in phase with the oscillations appearing in the input circuit of the tube 20. The amplitude of the amplified oscillations thus fed back through the condenser 50 to the input circuit of the tube 20 are so controlled by adjustment of the contact 41 of the potentiometer 38 as to maintain the system in oscillation at a satisfactory level but not at a sufficiently high level as to overdrive the system and cause an unstable oscillatory condition.

The resultant oscillations after amplification in the amplifier 52 are rectified by the demodulator 54 to derive across the potentiometer 64 a negative gain control unidirectional potential having an amplitude varying with the amplitude of oscillation of the oscillatory system 19. A portion of this gain control potential, as determined by manual adjustment of the position of the potentiometer contact 65, is applied through the filter network comprised by the resistors 66 and 67 and the condenser 40 to the control electrode 34 of the tube 33 for purposes of controlling the transconductance and thereby the gain of this tube. The time constant of the filter network 40, 66 and 67 is so selected by adjustment of the resistor 66 that the gain control potential in controlling the gain of the tube 33 tends to maintain the steady-state amplitude of oscillation substantially constant for all except relatively short transient amplitude changes. This feature makes the circuit relatively immune to drift and largely eliminates any need for resetting or adjustment after the instrument is installed. This is a unique feature. Conveyor belt speeds ordinarily range from perhaps 100 feet per minute to 400 feet per minute. For lower belt speeds, it is desirable to increase the time constant of the network 66, 67 and 40 by increasing the value of the resistor 66. Otherwise the compensating action of the gain control circuit may be fast enough to level out the change of amplitude of oscillation as a piece of tramp metal passes through the exploring inductor. Conversely, higher belt speeds make it desirable to decrease the time constant of the filter time-constant network to permit the oscillator to recover normal amplitude more rapidly after change of its oscillation amplitude produced by a piece of tramp metal passing through the exploring inductor. Quick recovery enables the system to indicate the presence of a second piece of tramp metal following closely behind the first. While belt speeds of 100 feet per minute and

400 feet per minute are cited as being the limits of a representative range, it will be understood that these values are merely representative and that the upper and lower belt speeds are not critical.

In addition to the oscillation amplitude control provided by adjustment of the potentiometer 38 and the action of the gain control potential as last mentioned, it will be apparent that the feed back condenser 50 has a reactive impedance varying with the value of capacitance of this condenser so that manual adjustment of its capacitance may also vary the oscillation amplitude by increasing or decreasing the magnitude of the feed-back energy. Furthermore, the reactance of the condenser 50 varies inversely with the frequency of oscillation of the oscillatory system so that increasing frequency effects an increase in the magnitude of the feed-back energy and vice versa. The importance of this will become apparent upon consideration of the effect of varying quantities and qualities of magnetic ore moving on the conveyor belt through the window of the exploring inductor 13. The finely divided iron oxide in the ore provides additional paths for the magnetic flux around the inductor 13 so that the inductance, and thereby the impedance, of the inductor increases with the quantity (and also the quality) of ore moving through the inductor. Any such increase in impedance will produce a corresponding increase in the amplitude of oscillations because a given value of feed-back energy through the condenser 50 is enabled to develop a larger oscillatory voltage in the input circuit of the tube 20 and this in turn causes a corresponding increase in the amplitude of the feed-back energy. However, the same effect which increases the inductance and impedance of the inductor 13 also lowers the frequency of the generated oscillations because the frequency of oscillation of the system is determined by the combined inductance of the inductor 13 and the fixed value of capacitance of the condenser 25. Thus two effects take place in direct ratio to the increasing amount and quality of magnetic ore moving through the window of the inductor 13; first the amplitude of the generated oscillations is increased, and secondly the frequency of the oscillations is decreased.

The foregoing description of the oscillatory system operation neglects the effect of the variable feed back condenser 50. If the capacitance of the condenser 50 is made quite large, as for example of the order of 300 micromicrofarads, the system will operate as above described. On the other hand, if the capacitance of the condenser 50 is of smaller value (perhaps of the order of 150 micromicrofarads) a condition can be obtained where the voltage drop across the reactive impedance of the condenser 50 increases with decreasing oscillation frequency in the same ratio as the impedance of the inductor 13 increases. In this case, any tendency of the oscillatory voltage across the tuned circuit 13, 25 to increase due to increase of impedance of the inductor 13 by a larger quantity or higher quality of magnetic ore passing through the window of the latter is counteracted or neutralized by a reduction in the amount of energy fed back through the condenser 50 due to the higher voltage drop across the latter caused by the lower oscillatory frequency resulting from the increased value of inductance of the inductor 13. Therefore, by appropriate choice or adjustment of the value of capacitance of the feed-back condenser 50, a stabilized amplitude characteristic can be established for the oscillatory system 19 such that the amplitude of oscillation does not change even though the quantity of ore moving through the window of the inductor 13 varies from zero to the full extent that can pass through the window. This value of the condenser 50 provides tight amplitude stabilization for varying quantities of ore, and is readily established by adjustment in practice since too large a value will result in an increase of oscillation amplitude with

increasing quantities of ore moving through the inductor 13 whereas too small a capacity will result in a decrease of oscillation amplitude with increasing quantities of ore moving through the inductor.

In initially adjusting the oscillatory system operation to attain the amplitude-stabilized characteristic last described, the potentiometer 38 is adjusted concurrently with adjustment of the value of capacitance of the condenser 50. As pointed out above, the oscillatory system 19 is operated at a standard oscillation level such that the amplifier tubes 20 and 33 essentially operate as linear amplifiers and at an oscillation level sufficiently low that it does not cause either of the control electrodes 21 and 34 to draw any appreciable control-electrode current by peak rectification of the oscillations applied to the control electrodes. To this end, each time that the feed-back condenser 50 is adjusted to a different value of capacitance the contact 41 of the potentiometer 38 is also adjusted to restore the oscillatory system 19 to its predetermined or standard oscillation level. The desired operating condition of the system, effected by adjustment of the condenser 50 and potentiometer 38, is the one mentioned above where any quantity of ore from zero to maximum may be moved through the window of the exploring inductor 13 without appreciably changing the amplitude level of oscillations generated by the oscillatory system 19. To facilitate adjustment of the condenser 50, it is preferably provided with a large calibrated dial and a lock for locking the condenser in adjusted position.

With the system adjusted for optimum operation in the manner just described, any metallic body whether magnetic or nonmagnetic upon entering the field of the exploring inductor 13 has high frequency eddy currents induced in it. These induced eddy currents cause the resistive component of impedance of the exploring inductor 13 to increase. This causes the oscillatory circuit 13, 25 to be more heavily loaded and thereby causes the amplitude of oscillation to decrease (in severe cases the oscillatory system may cease to oscillate entirely). It will be appreciated that this change of oscillation amplitude is of transitory nature, occurring only during the interval the conductive metal moves within the high-frequency field of the inductor 13. The time constant of the gain control system filter network 40, 66 and 67 is selected sufficiently long that the gain control system is not effective to change the gain of the tube 33 rapidly enough to counteract to any appreciable extent any such transient amplitude change as last described.

The amplifier 52 amplifies these transient amplitude changes, and the demodulator 54 peak rectifies the amplified oscillations to derive a transient voltage across its load resistors 63 and 64. This transient voltage is applied to one or more low-frequency amplifier stages of the unit 55, which may include one or more integrating networks to sharpen the transient nature of the derived voltage, and the amplified transient voltage may be used to trigger one or more tandem arranged gas discharge devices the last of which controls the operation of the relay 56.

Thus by amplifying the output of the oscillatory system 19 to detect small transient decreases in oscillation amplitude, very small pieces of tramp metal may be detected. Since, as pointed out above, the quantity and quality of ore moving through the window of the inductor 13 have substantially no effect on the oscillation amplitude, such small pieces of tramp metal may be detected regardless of whether the window of the inductor 13 is empty, partially filled, or full of moving ore. It has been found in practice that this is true even though the ore is saturated with water. A representative sensitivity setting of the system may be made such that the system indicates the presence of a badly worn nonmagnetic steel dipper tooth having approximate dimensions

of four inches wide, five inches high, and three inches deep. With this setting, the presence of much smaller pieces of magnetic steel of the approximate order of one-quarter of the mass of the nonmagnetic dipper tooth will readily be indicated. This order of sensitivity has been found in practice to provide operation free from false indications from pieces of conductive ore while at the same time providing sufficient sensitivity to detect pieces of tramp metal large enough to damage the ore crusher.

The component values shown in the drawing are included merely as representing values which had been found satisfactory in practice and are not intended to limit the invention to any particular design constants.

It will be apparent from the foregoing description of the invention that an oscillatory system embodying the invention exhibits high transient response to moving conductive bodies of a wide range of sizes while yet exhibiting relatively little or no response either transient or otherwise to a moving body of magnetic ore of widely varying quantity and quality. Thus the oscillatory system of the invention is relatively free of undesired false response to reactive electrical properties of varying quantities and qualities of moving magnetic ore as well as to long term changes in system operating parameters while yet retaining optimum desired transient response to resistive electrical properties of moving conductive bodies even of relatively small size. It will be evident that these novel operating characteristics directly result from the ability of the system to use the reactive component of impedance of the exploring inductor primarily to control the operating frequency, but to have substantially no effect on the oscillation amplitude, whereas the resistive component of impedance of the exploring inductor primarily controls the transient oscillation amplitude changes and thereby enables the system to have high and stabilized sensitivity for detection of conductive bodies either of magnetic or nonmagnetic metal.

While a specific form of the invention has been described for purposes of illustration, it is contemplated that numerous changes may be made without departing from the spirit of the invention.

What is claimed is:

1. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, and frequency-responsive oscillation-sustaining means for rendering the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

2. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, and frequency-responsive oscillation-sustaining means for rendering the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window while permitting transient amplitude changes of said generated oscillations caused by transient change in the resistive impedance of said inductor due to passage of conductive bodies through the window thereof.

3. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled

by said circuit, said means including an oscillatory-energy feed-back path for at least partially sustaining the generation of said oscillations, and an impedance having an impedance component varying with the frequency of generated oscillations to control the magnitude of energy fed back by said path inversely with changes of impedance of said inductor caused by changing magnetic properties of magnetic ore moving through said window.

4. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, and oscillation-sustaining means including impedance means having an impedance component varying with the frequency of said generated oscillations for rendering the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

5. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for amplifying electrical oscillations generated in said circuit, and an oscillation-sustaining feed-back path including an impedance element having an impedance component varying with the frequency of said generated oscillations for rendering the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

6. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for amplifying electrical oscillations generated in said circuit, and an oscillation-sustaining energy-feed-back condenser having a value selected to render the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

7. An oscillatory system adapted to detect conductive bodies in relatively non-conductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, reactive means having a reactive impedance varying with frequency, and oscillation-sustaining energy-translating means including said resonant circuit and said reactive means for generating sustained oscillations having substantially constant amplitude with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

8. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, frequency-responsive oscillation sustaining means for exerting a control over the amplitude of generated oscillations inversely with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window, and means including an amplitude demodulator for maintaining a substantially linear input-output oscillation translation characteristic in said oscillation generating means for oscillation amplitude changes other than those transient amplitude changes due to change in the resistive imped-

ance of said inductor by the passage of conductive bodies through said window.

9. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, oscillatory energy amplifying means having an input circuit including said resonant circuit and an output circuit in which amplified oscillatory energy is developed and exhibiting a substantially linear input-output amplitude translation characteristic for any amplitude of input-circuit oscillations below a predetermined value and means having an oscillation translation characteristic varying with frequency for translating oscillatory energy from said output circuit to said input circuit to generate sustained oscillations having input-circuit amplitude less than said predetermined value and remaining substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

10. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, oscillatory-energy amplifying means having an input circuit including said resonant circuit and an output circuit in which amplified oscillatory energy is developed and exhibiting a substantially linear input-output amplitude translation characteristic for any amplitude of input-circuit oscillations below a predetermined value, a first translation means having an oscillation translation characteristic substantially independent of oscillation frequency for adjustably controlling the amplification ratio of said amplifying means, and a second translation means having an oscillation translation characteristic varying with frequency for translating oscillatory energy from said output circuit to generate sustained oscillations having under control of said first translating means an input-circuit amplitude less than said predetermined value, the related magnitudes of oscillatory energy translated by said first and second translating means being selected to maintain the input-circuit amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

11. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, oscillatory energy amplifying means having an input circuit including said resonant circuit and an output circuit in which amplified oscillatory energy is developed and exhibiting a substantially linear input-output amplitude translation characteristic for any amplitude of input-circuit oscillations below a predetermined value, feed-back means having an oscillation translation characteristic varying with frequency for translating said oscillatory energy from said output circuit to said input circuit to generate sustained oscillations, and a relatively long-time-constant automatic gain control system coupled to said output circuit and responsive to said generated oscillations for controlling the gain of said amplifying means to maintain the steady-state input-circuit amplitude of said oscillations less than said predetermined value, the value of energy fed back by said feed-back means being selected to render the steady-state oscillation amplitude substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

12. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, oscillatory energy amplifying means hav-

ing an input circuit including said resonant circuit and an output circuit in which amplified oscillatory energy is developed, means having an oscillation translation characteristic varying with frequency for translating oscillatory energy from said output circuit to said input circuit to generate sustained oscillations, and a gain control system for controlling the gain of said amplifying means to maintain a steady-state linear input-output amplitude translation characteristic thereof and including a relatively long-time-constant impedance network establishing a limit for the maximum duration of detectable transient changes of amplitude of the generated oscillations, the steady-state value of said feed-back energy being selected to maintain the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window but to permit transient amplitude changes in response to conductive bodies passing through said window.

13. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, a multi-stage tandem arranged resistance coupled amplifier having an input circuit including said resonant circuit and an output circuit in which amplified oscillatory energy is developed and exhibiting a substantially linear input-output amplitude translation characteristic for any amplitude of input-circuit oscillations below a predetermined value and a substantially constant input-output amplitude translation characteristic over a predetermined frequency band, and means having an oscillation translation characteristic varying with frequency for translating oscillatory energy from said output circuit to said input circuit to generate sustained oscillations within said frequency band and of an input-circuit amplitude less than said predetermined value and remaining substantially constant with changes of reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window.

14. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, reactive means having a reactive impedance varying with frequency, oscillation amplifying means including a gain control system for maintaining the operation of said amplifying means within a substantially linear input-output translation characteristic, and an oscillation-sustaining energy feed-back translating path including said resonant circuit and said reactive means for feeding oscillatory energy from the output circuit to the input circuit of said amplifying means to generate sustained oscillations having substantially constant amplitude with changes of the reactive impedance of said inductor caused by varying magnetic properties of magnetic ore while permitting transient amplitude changes with changes of the resistive impedance of said inductor caused by conductive bodies passing through said window.

15. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, oscillation amplifying means including a gain control system for maintaining the operation of said amplifying means within a substantially linear input-

output translation characteristic, and an oscillatory-energy feed-back path including a condenser and said resonant circuit in series in said path for coupling oscillatory energy from the output circuit to the input circuit of said amplifying means to generate sustained oscillations of substantially constant amplitude with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window while permitting transient amplitude changes with the resistive impedance of said inductor caused by conductive bodies passing through said window.

16. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, frequency-responsive oscillation-sustaining means for rendering the amplitude of said generating oscillations substantially constant with change of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window, and means for detecting transient amplitude changes of said generated oscillations with transient change in the resistive impedance of said inductor due to passage of conductive bodies through the window thereof.

17. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, an oscillation-sustaining energy-feed-back condenser having a value selected to render the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window, and a peak rectifier responsive to said generated oscillations for detecting transient amplitude changes thereof with transient change in the resistive impedance of said inductor due to passage of conductive bodies through said window.

18. An oscillatory system adapted to detect conductive bodies in relatively nonconductive magnetic ore comprising, a resonant electrical circuit including an exploring inductor having a window through which a flow of ore may move, means including said resonant circuit for generating electrical oscillations of frequency controlled by said circuit, frequency-responsive oscillation-sustaining means for rendering the amplitude of said generated oscillations substantially constant with changes of the reactive impedance of said inductor caused by changing volumes of magnetic ore passing through said window, means for detecting transient amplitude changes of said generated oscillations with transient change in the resistive impedance of said inductor due to passage of conductive bodies through the window thereof, and means responsive to said detected transient amplitude changes for providing a control effect indicating the presence of said conductive body at said window.

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