

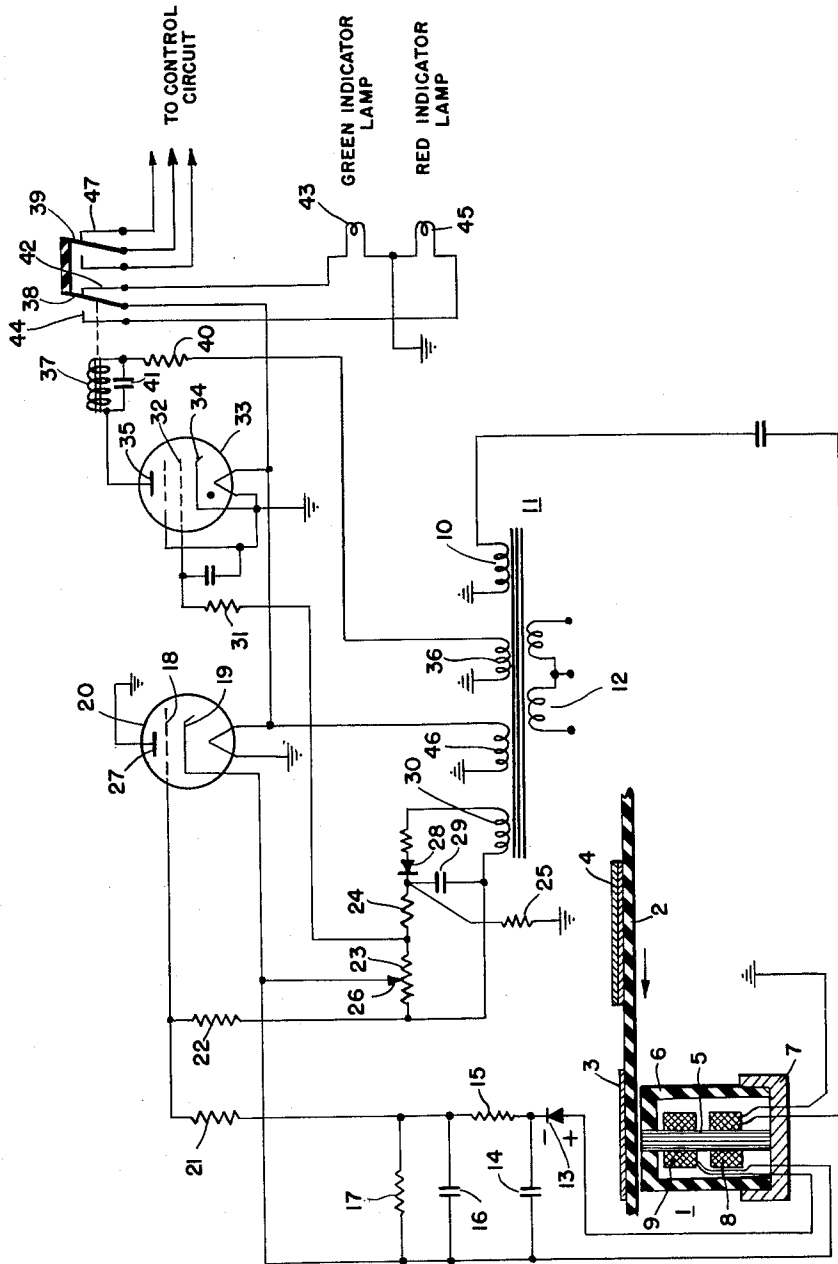
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MAGNETIC DETECTOR

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MAGNETIC DETECTOR

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This invention relates to magnetic detectors and more particularly to apparatus for gauging or measuring thickness of ferro-magnetic sheet material.

There are numerous industrial applications for magnetic sheet thickness detectors and indicators. Such devices are very frequently employed to prevent the jamming or disabling of automatic sheet feeding machinery in the canning industry. Metal sheets comprising the blanks for the cans to be fabricated are fed along a conveyor belt to the processing equipment. In the event that two or more sheets should inadvertently stick together or otherwise enter the processing equipment in partially or fully superposed relationship, serious injury to the machinery may ensue unless means are provided for automatically shutting off the power whenever such a situation occurs. There are also numerous other applications for magnetic sheet thickness detectors and indicators; for example, such apparatus may be employed in conjunction with a servo system to provide automatic control of the thickness of rolled sheet material. Also equipment of this type may be useful in sorting metal sheet materials of different thicknesses.

Early attempts at providing thickness indication or detection for use in conjunction with automatic shut-off apparatus or servo systems of one sort or another employed mechanical feeler elements which were preset to be actuated only upon the approach or passage of sheet material of greater than a predetermined desired thickness. However, mechanical arrangements of this type are not particularly accurate and are easily thrown out of adjustment. Consequently, electrical systems were devised which exhibited greater sensitivity and reliability.

Thus, for example, it is known that a magnetic thickness detector or indicator may comprise an open core electromagnet disposed in the path of the ferro-magnetic sheet metal blanks as they are transferred along a conveyor. As a metal can blank passes over the open end of the electro magnet, the flux within the core is increased and this gives rise to an increase in the voltage across the electromagnetic energizing coil. This increased voltage may be detected and employed in any desired way as a control signal of effect a control operation or to give visual or audible indication of the presence of the sheet metal. If desired, the device may be set up in such a way that only sheet metal of greater than a predetermined thickness will give an output signal of sufficient magnitude to perform the desired control operation; thus, the control signal developed in the presence of two superposed sheets may be employed to deenergize a power circuit or perform any other desired control operation. However, such devices as have been heretofore employed, have been extremely critical in their adjustments and have been incapable of detecting sufficiently fine thickness differences and variations to accommodate all of the required applications for devices of this sort. In many installations it has been necessary to recheck and reset the associated control circuit at very frequent intervals, in order to maintain the accuracy and stability imposed by present day production techniques and requirements.

It is accordingly a principal object of the present invention to provide a magnetic thickness detector or indicator which avoids one or more of the disadvantages of prior art devices.

It is a more specific object of the invention to provide

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a new and improved magnetic thickness detector or indicator which is considerably more stable and less critical in its operation than prior art devices of this type.

Another object of the invention is to provide a new and improved metal thickness detector or indicator which may be employed to detect very minute differences or changes in thickness, of the order of two or three thousandths of an inch, with complete reliability.

The particular features of the invention which are believed to be novel are set forth in detail in the accompanying claims. The invention, together with further objects and advantages thereof, may more readily be understood, however, by reference to the following description taken in conjunction with the accompanying drawing, in which the single figure is a schematic circuit diagram of a magnetic thickness detector or indicator constructed in accordance with the present invention and adapted specifically for use as a double sheet detector or the like.

In the drawing, a magnetic detector head 1 is placed below a moving conveyor belt 2 which is powered by any suitable mechanical or electrical drive arrangement and usually includes an electric motor (not shown). The motor may drive the conveyor belt in the direction indicated by the arrow over a path passing directly over the magnetic detector head 1. Ferro magnetic sheet metal elements such as metal can blanks 3 are individually supplied to the conveyor 2 in any suitable manner, usually by means of automatic feeding from a magazine or hopper (not shown), and occasionally two or more of the metal can blanks may stick together or otherwise be supplied to the conveyor in superposed or overlying relationship as indicated at 4.

Magnetic detector head 1 is preferably constructed as an open-core transformer comprising a laminated central core 5 supported within a housing or casing 6 of non-metallic material such as Bakelite or other suitable plastic. The upper end of the laminated core 5 projects through the plastic housing 6 and is flush with the upper surface thereof; the other end of the core terminates in a base or cap 7 constructed of iron or other ferro-magnetic material. The primary and secondary windings 8 and 9, respectively, of the transformer are wound on laminated core 5 with the secondary winding 9 in the upper portion of the housing closest to the open end of core 5.

Primary winding 8 of the magnetic detector head is energized from a suitable source of alternating current such as the secondary winding 10 of a power transformer 11, the primary winding 12 of which may be connected to a 115-volt 2-wire or 230-volt 3-wire power source, such as the 60-cycle public utility power lines (not shown).

One terminal of secondary winding 9 of magnetic detector head 1 is connected to the negative terminal of a rectifier 13, preferably of the selenium dry-disk type, the positive terminal of which is connected to a filter condenser 14 which is returned to the other terminal of secondary winding 9. The unidirectional or D.C. control voltage developed by rectifier 13 is further filtered by means of a series resistor 15 and a pair of parallel elements comprising a condenser 16 and a resistor 17 and applied between the control grid 18 and the cathode 19 constituting the input terminals of an electron-discharge device 20 which may constitute a simple triode amplifier tube.

The unidirectional or D.C. voltage developed by rectifier 13 and appearing across the parallel combination of filter condenser 16 and resistor 17 is applied across a portion of a resistive voltage divider comprising a plurality of series-connected resistors 21, 22, 23, 24 and 25 which are connected in the recited sequence between resistor

15 and a plane of fixed reference potential, here shown as ground. Resistor 23 is provided with a variable contact 26 which is directly connected to cathode 19 of electron-discharge device 20. Resistor 17 is connected between cathode 19 and the end of resistor 21 opposite resistor 22. Control grid 18 of device 20 is connected to the junction between resistors 21 and 22, and the anode 27 of device 20 is directly connected to ground with anode 27 and cathode 19 constituting the output terminals of device 20. Cathode 19 of device 20 is maintained at an appropriate unidirectional or D.C. voltage of negative polarity which is developed by a rectifier 28 and filter condenser 29 connected across a separate secondary winding 30 of power transformer 11; the junction between resistors 24 and 25 is connected to the cathode terminal of rectifier 28 to provide electron space current within electron-discharge device 20 under the control of the voltage supplied to control grid 18.

The junction between resistors 23 and 24 is coupled through a current limiting resistor 31 to the control grid 32 of a control device for amplifier 33 which may constitute a conventional gas discharge device or thyatron having grid 32 and a cathode 34 as its input terminals. The cathode 34 of device 33 is directly connected to ground, and the anode or plate 35, which with cathode 34 constitutes the output terminals of device 33, is energized with alternating voltage supplied by an additional secondary winding 36 of power transformer 11. The plate circuit of device 33 includes the control winding 37 of a relay or controlled element provided with a pair of moving contacts 38 and 39. The plate circuit of device 33 may also include a series-connected current limiting resistor 40 as well as an anti-chatter condenser 41 connected across relay coil 37. Moving contact 38 normally engages a fixed contact 42 which is connected through the filament of a green indicator lamp 43 to ground. When the relay is energized, moving contact 38 engages another fixed contact 44 which is connected through the filament of a red indicator lamp 45 to ground. The filaments of electron-discharge device 20, thyatron 33, and indicator lamps 43 and 45 are all energized from an additional secondary winding 46 of power transformer 11, and either one or the other of the indicator lamps 43 and 45 is always energized depending upon the instantaneous condition of moving contact 38 of the control relay.

Moving contact 39 of the control relay normally engages a fixed contact 47 to close the power supply circuit for the conveyor motor (not shown). However, when the control relay is actuated by firing thyatron 33, moving contact 39 disengages fixed contact 47 to open the power circuit to the driving motor and avoid damage to the equipment. The control circuit for effecting automatic deenergization of the conveyor motor may be completely conventional and accordingly has not been shown.

In operation, the alternating voltage appearing across the secondary winding 30 of power transformer 11 is rectified by device 28 to provide a unidirectional bias voltage across condenser 29. At the same time, the alternating voltage developed across the secondary winding 10 of power transformer 11 is applied to the primary winding 8 of magnetic detector head 1. The voltage induced in secondary winding 9 of magnetic detector head 1 is rectified by device 13 and filtered by resistors 15, 17 and condensers 14, 16 to provide a D.C. or unidirectional control voltage whose amplitude is dependent upon the presence or absence of ferro-magnetic material within the field of the open-core transformer which constitutes magnetic detector head 1. In the absence of any ferro-magnetic material within the field of the open-core transformer or magnetic detector head, the voltage developed across resistor 17 and applied between grid 18 and cathode 19 is only a few volts positive as viewed from grid to cathode. The voltage divider portion comprising resistors 23 and 24 is connected across the D.C. power

source composed of diode 28 and secondary winding 30, the junction of resistor 23 with resistor 22 being the negative end of this divider portion. A D.C. bias voltage negative with respect to anode 27 is therefore applied to cathode 19 of electron-discharge device 20 to condition that device for the conduction of electron space current to anode 27. By virtue of the potential difference between contact 26 and the negative end of resistor 23, grid 18 is biased via resistor 22 negatively with respect to cathode 19. The voltage applied between control grid 18 and cathode 19, in the quiescent condition, is substantially negative, biasing device 20 beyond anode current cut-off. In this condition of the circuit, D.C. voltage negative with respect to cathode 34 is applied through resistor 31 to control grid 32 of thyatron 33, thus preventing control tube 33 from firing and leaving relay 37 in the unenergized condition. Thus, in the quiescent state green indicator lamp 43 is illuminated and the control circuit for the conveyor drive system remains energized through contacts 39 and 47 of the control relay.

When a single sheet of ferro-magnetic material, such as stainless steel or the like, is placed in juxtaposition with magnetic detector head 1, as illustrated at 3 in the drawing, the flux concentration in laminated core 5 is greatly increased and the output voltage developed across secondary winding 9 is correspondingly increased. This leads to a considerably larger positive D.C. voltage developed at the output of rectifier 13 and filter 14, 15, 16, 17, raising the potential of control grid 18 in a positive direction with respect to cathode 19 but not to an extent sufficient to cause any substantial flow of electron space current in device 20, because the portion of the voltage developed by rectifier 28 and applied between grid 18 and cathode 19 remains substantially unchanged at a rather high negative value. The potential applied to control grid 32 of control tube 33 remains less than that required to initiate a gas discharge in tube 33; consequently, control relay 37 remains in an unenergized condition and the conveyor continues to operate.

However, in the presence of a pair of superposed metal sheets, as indicated at 4, the voltage developed by secondary winding 9 of magnetic detector head 1 is further increased and the D.C. control voltage developed by rectifier 13 and applied between grid 18 and cathode 19 becomes sufficiently large to initiate electron space current between cathode 19 and anode 27. In this condition, electron-discharge device 20 functions as a D.C. amplifier in a cathode follower impedance bridge circuit, the output load impedance of which constitutes the series combination of resistors 24, 25 bridged with a variable portion of resistor 23 and the space-current path of device 20. That is, the bridge essentially includes as its four arms resistor 24, resistor 25, a portion of resistor 23 and the output terminals of device 20. The D.C. power source constituting rectifier 28 and winding 19 is coupled across one diagonal of the bridge, and the bridge output across its other diagonal is coupled to grid 32 and cathode 34 of thyatron 33. In order to provide sensitivity control, a variable portion of resistor 23 is included in series with the direct current applied across the one diagonal. The cathode follower action and resulting D.C. amplification causes the voltage at the junction between resistors 23 and 24 to become less negative and attain a positive value relative to the voltage on cathode 34. When this positive voltage is applied through resistor 31 to control grid 32 of thyatron 33, ionization within the envelope is initiated and a gas discharge ensues to energize relay 37. This breaks contact 38, 42 to extinguish green indicator lamp 43, and closes contacts 38, 44 to illuminate red indicator lamp 45 indicating the presence of an undesirable condition, e.g., a pair of superposed sheet metal elements on the conveyor 2. At the same time, contacts 39 and 47 are broken to open the conveyor drive circuit and automatically stop the equipment before the improper condition can result in any substantial damage. Other

control functions may also be performed in response to firing of thyatron 33, as is well understood in the art.

The illustrated system provides considerably increased stability and much greater flexibility in operation than previously known magnetic thickness detectors or indicators. Potentiometer resistor 23 may be employed as a sensitivity control to preset the apparatus for any desired thickness of ferro-magnetic sheet material. In many commercial canning operations, metal can blanks of about eight or nine thousandths inch thickness are conventionally employed. To set up the circuit to accommodate sheet metal of this or any other desired gauge, a single thickness of such sheet metal is placed over magnetic detector head 1 and variable contact 26 is moved to the right (as viewed in the drawing) until the green indicator lamp 43 is extinguished and red indicator lamp is illuminated. Control element 26 is then adjusted in the opposite direction until the red indicator lamp drops out and the green indicator lamp is again illuminated. The equipment is then accurately and reliably adjusted to detect any condition of overlapping thicknesses of sheet metal on the conveyor as it passes over the magnetic detector head. Thickness differences as small as two or three thousandths of an inch may be accurately and reliably detected with this arrangement.

Much of the added sensitivity provided by the arrangement of the present invention as compared with previously known systems is attributable to the use of the D.C. amplifier between the control voltage generator and the control tube 33. By employing a sharp cut-off amplifier tube 20 and by suitably arranging the bias voltages it can be assured that amplification of the control voltage occurs only when the undesired condition occurs. In other words, in the presence of a single sheet of ferro-magnetic material, the amplifier tube 20 remains biased beyond cut-off and contributes nothing to the voltage applied to the control grid of thyatron 33. On the other hand, as a pair of superposed ferro-magnetic sheets approach the magnetic detector head, the positive voltage applied to control grid 18 increases to a sufficient extent to permit substantial anode current flow and develop a large positive D.C. voltage across the output impedance of the cathode follower comprising tube 20. This positive voltage insures positive firing of the gas discharge tube whenever undesired condition is encountered. In this connection, the use of a limiting resistor 31 in the grid circuit of thyatron 33 is of considerable advantage in providing an increased sensitivity for the system. With resistor 31 the amplified control voltage appearing across the series combination of resistors 24 and 25 need only become sufficiently positive to initiate gas discharge; the presence of resistor 31 inhibits the flow of grid circuit current and prevents that voltage from dropping before gas discharge has been fully initiated thus preventing misfiring of the control thyatron.

Merely by way of illustration and in no sense by way of limitation, the illustrated system may be constructed with components having the following characteristic values and type designations:

Electron-discharge device 20 . . . triode section of a type 6AQ6 tube;

Thyatron 33	-----type--	2D21
Resistor 15	-----ohms--	15,000
Resistor 17	-----do-----	47,000
Resistor 21	-----megohm--	1/2
Resistor 22	-----do-----	1/2
Resistor 23	-----ohms--	50,000
Resistor 24	-----do-----	6,800
Resistor 25	-----do-----	82,000
Resistor 31	-----megohm--	1
Resistor 40	-----ohms--	1,000
Condenser 14	-----microfarad--	0.5
Condenser 16	-----do-----	0.25
Condenser 29	-----do-----	8
Condenser 41	-----do-----	1

The control relay may be of standard construction comprising a 3,000-ohm energizing coil 37 and adjusted to pull in with 8 milliamperes of current in energizing coil 37 and to drop out at 4 milliamperes energizing coil current.

Although the invention has been shown and described in connection with its preferred application as a magnetic double sheet detector, it is apparent that the invention may be utilized to equal advantage in conjunction with automatic thickness control systems, in magnetic thickness measuring devices and indicators, and in numerous other applications. In each instance, it is found that the system according to the present invention provides greatly increased sensitivity, flexibility, and reliability as compared with previously employed systems.

While the invention has been shown and described in connection with a presently preferred embodiment, it is apparent that numerous changes and modifications can be made, and the appended claims are therefore contemplated to cover all such variations and modifications as may occur to those skilled in the art to which the invention pertains.

I claim:

1. Material thickness detection apparatus comprising: means responsive to increased thickness of said material to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said means and responsive to said control signal; an impedance bridge having said direct current amplifier output terminals incorporated in one leg thereof; a direct current power source coupled essentially across one diagonal of said bridge; a control amplifier having input and output terminals with its input terminals coupled across the other diagonal of said bridge; and a controlled element coupled to and energized by said control amplifier output terminal.

2. Magnetic material thickness detection apparatus comprising: magnetic field generating means responsive to an increased thickness of said magnetic material within said field to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said generating means and responsive to said control signal; an impedance bridge having said direct current amplifier output terminals incorporated in one leg thereof; a direct current power source coupled essentially across one diagonal of said bridge; a control amplifier having input and output terminals with its input terminals coupled across the other diagonal of said bridge; and a controlled element coupled to and energized by said control amplifier output terminals.

3. A magnetic material thickness detection apparatus comprising: a housing substantially of non-magnetic material; an elongated core of magnetic material disposed in said housing; a first coil wound on said core; a source of potential coupled to and energizing first coil; a second coil wound on said core and inductively coupled thereby to said first coil to generate a field emanating from said housing; means responsive to the presence of a changing thickness of said material within said field to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said means and responsive to said control signals; an impedance bridge having said direct current amplifier output terminals incorporated in one leg thereof; a direct current power source coupled essentially across one diagonal of said bridge; a control amplifier having input and output terminals with its input terminals coupled across the other diagonal of said bridge; and a controlled element coupled to and energized by said control amplifier output terminals.

4. Material thickness detection apparatus comprising: means responsive to increased thickness of said material to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said means and responsive to said control sig-

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nal; a direct current power source; an impedance bridge with said direct current amplifier output terminals incorporated in one leg of said bridge and said direct current power source variably coupled across one diagonal of said bridge; a control amplifier having input and output terminals with its input terminals coupled across the other diagonal of said bridge; and a controlled element coupled to and energized by said control amplifier output terminals.

5. Material thickness detection apparatus comprising: means responsive to increased thickness of said material to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said means and responsive to said control signal; an impedance bridge having said direct current amplifier output terminals incorporated in one leg thereof; a direct current power source coupled essentially across one diagonal of said bridge; a control amplifier having input and output terminal with its input terminals coupled across the other diagonal of said bridge and responsive only to signal levels across said other diagonal exceeding a predetermined threshold value for developing an output signal; and a controlled element coupled to said control amplifier output terminals and energized by said output signal.

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6. Material thickness detection apparatus comprising: means responsive to increased thickness of said material to develop a control signal; a direct current amplifier having input and output terminals with its input terminals coupled to said means and responsive to said control signal; an impedance bridge having said direct current amplifier output terminals incorporated in one leg thereof; a direct current power source coupled essentially across one diagonal of said bridge; a control amplifier including a thyatron having input and output terminals; an impedance; means coupling the input terminals of said thyatron across the other diagonal of said bridge through said impedance; and a controlled element coupled to and energized by said control amplifier output terminals.

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