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APPARATUS FOR ANALYZING MOISTURE CONTENT

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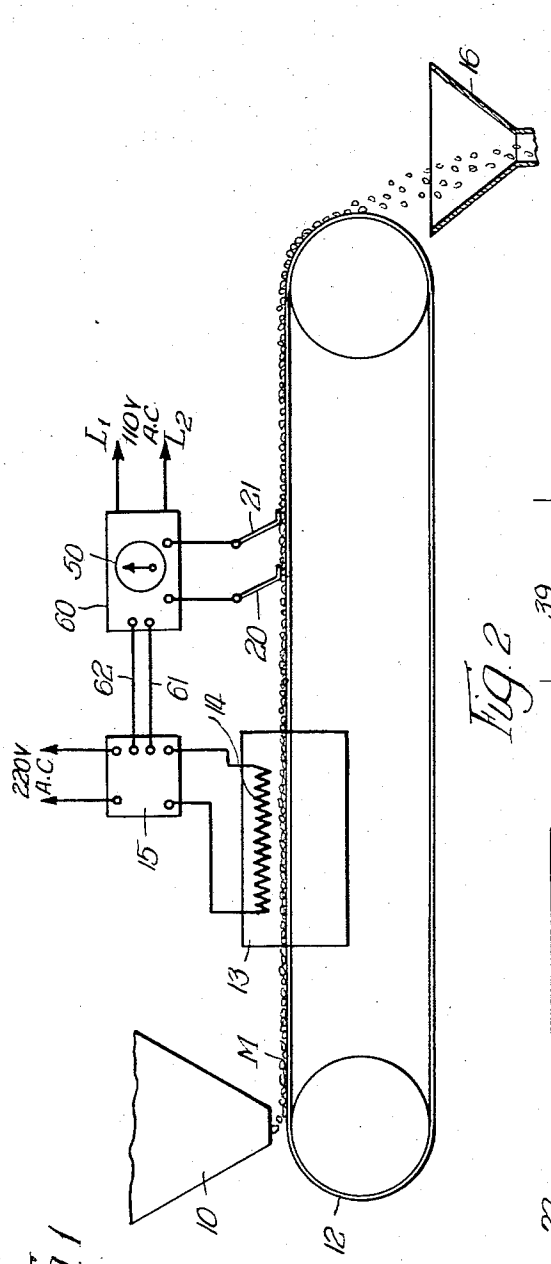


Fig. 1

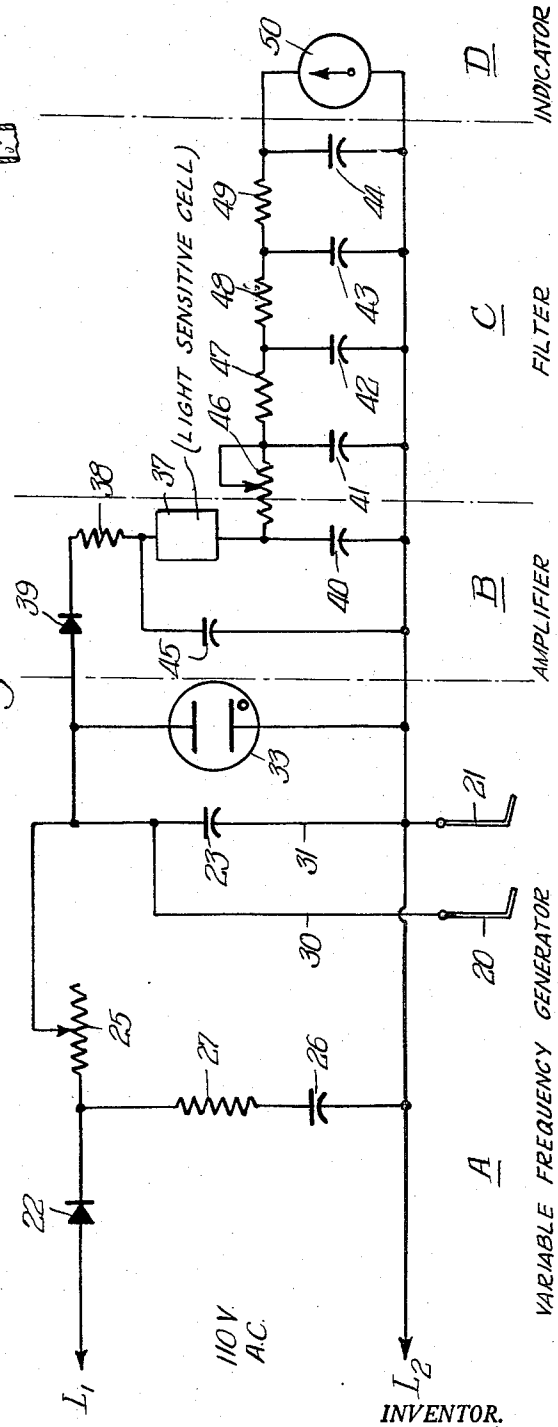


Fig. 2

INVENTOR.
Thomas R. Smith,
BY
William G. Landwier
AGENT

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APPARATUS FOR ANALYZING MOISTURE CONTENT

Thomas R. Smith, 710 W. 11th St. S., Newton, Iowa 50208

Continuation of application Ser. No. 177,584, Mar. 5, 1962. This application Nov. 18, 1966, Ser. No. 595,535
19 Claims. (Cl. 34—48)

This is a continuation of Ser. No. 177,584, filed Mar. 5, 1962, now abandoned, said application Ser. No. 177,584 being a continuation-in-part of Ser. No. 22,323, filed Apr. 14, 1960, now abandoned, and Ser. No. 153,473, filed Nov. 20, 1961, now abandoned.

This invention relates to an apparatus for analyzing the moisture content of materials, and more particularly to a system for detecting the moisture content upon contacting random pieces of material.

It is often desirable to measure the moisture content of fabrics, cotton bolls, raw wool, paper, and the like, either continuously, or batch-wise. While numerous systems have been devised, they contain inherent disadvantages. In some systems indirect measurements are made that are not consistently accurate. In other systems it is often difficult to obtain sufficient random samples for practical and useful determinations.

It is, therefore, an object of the invention to provide an apparatus for analyzing the moisture content of materials. It is another object of the invention to provide an apparatus for analyzing the moisture content of materials by direct measurement of their electrical resistance. It is yet another object of the invention to provide an apparatus for analyzing the moisture content of the material, which is adapted to be controlled by random pieces. It is still another object of the invention to provide an apparatus for analyzing the moisture content of the material, which may be employed in connection with a drying apparatus. Further objects and advantages of this invention will become evident as the description proceeds and from an examination of the accompanying drawing which illustrates several embodiments of the invention and in which similar numerals refer to similar parts throughout the several views.

In the drawing:

FIGURE 1 is a diagrammatic view of an apparatus for drying materials illustrating one form in which the invention may be utilized.

FIGURE 2 is a circuit diagram of a system for analyzing the moisture content of material embodying the invention, for example, as may be used in combination with the drying apparatus of FIGURE 1.

Referring now to FIGURE 1 of the drawing, there is illustrated a hopper **10** for depositing material M on conveyor **12**. The conveyor **12** conducts the material M received from hopper **10** through an oven **13** in order to be dried, and then discharges the dried material M in receptacle **16**. The oven **13** may be heated by electrical heating units **14** supplied with **220** volts A.C.

The electrical units **14** are regulated by control **15**, so as to vary the amount of heat supplied to the material M. It will be realized that the heat supplied to the material M also may be varied in several other ways, such as changing the speed of the conveyor **12**, or the number of heater units **14** energized in oven **13**.

A pair of electrodes **20, 21** are positioned for contacting and completing an electrical circuit through various pieces of the material M after it has traversed at least a portion of the drying period of oven **13**. A number of parallel electrodes similar to **20, 21** may be utilized so as to contact a large number of random pieces of material while advanced by the conveyor **12**.

Referring now to FIGURE 2, there is shown a system

for analyzing the moisture content of the material, such as on conveyor **12**. The system includes a circuit which may be energized by 110 volts A.C. supplied by power lines L_1, L_2.

A pulse generator A produces electrical pulses at a frequency controlled by the electrical resistance between electrodes **20, 21**. As the moisture content of the material M varies, the frequency of A changes, so that when the material is dry a relatively higher frequency is generated than when the material is wet.

When used in connection with a drying apparatus, such as shown in FIGURE 1, the pulses produced by A may have a frequency period of sufficient duration for random pieces of material to contact electrodes **20, 21**. Under probability principles, accuracy of the measurements are in proportion to the number of samples, so that it is desirable to have a long frequency period, without, of course, making the control too slow for efficient regulation of the drying operation.

The pulses produced by A are picked up and amplified by amplifier B, and then filtered by filter network C. The indicator D, which may have a meter **50**, registers the integrated value of pulses filtered by the filter C which reflects the relative amount of moisture contained in the material contacting electrodes **20, 21**.

The system for analyzing the moisture content, illustrated in FIGURE 2, may be mounted in unit **60**, as shown in FIGURE 1, associated with conveyor **12** for regulation of the heaters **14** in oven **13**, so as to control the degree of dryness of material M. By watching the meter **50**, an operator may regulate the moisture content of the material leaving the oven **13**, such as by changing the speed of the conveyor **12**, or varying the heat energy supplied to the oven through heating units **14**. The same regulation may be performed automatically, such as by lines **61, 62** to control **15**, so as to automatically vary the heat supplied to the heating units **14** in response to the moisture content of the material M contacted by electrodes **20, 21**.

The system of FIGURE 2 may be also utilized as an independent unit for analysis of material, even though it can be advantageously employed in combination with a drying apparatus.

Referring again to FIGURE 2, the pulse generator A includes a selenium half-wave rectifier **22**, connected on one side to line L_1. The other side of the rectifier is connected to capacitor **23** through variable resistor **25** and to capacitor **26** through resistor **27**. The other sides of capacitors **23, 26** are connected to power line L_2. Electrodes **20, 21** are connected across the capacitor **23** by lines **30, 31**. When the capacitor **23** is charged by D.C. current supplied by rectifier **22**, it may be discharged by any conducting material placed across, and shorting, the pair of electrodes **20, 21**, such as wet material M on conveyor **12** (FIGURE 1).

A gaseous discharge tube, such as neon lamp **33**, is connected across the capacitor **23**. The neon lamp **33** normally has an infinite resistance; however, when the charge on the capacitor **23** reaches a predetermined value, for example 76 volts, the gas in the tube is ionized, and electrical circuit conducted therethrough to produce a visible discharge.

By way of illustration, and not as a limitation of the invention, it has been found if the material M varies in its resistance from 500,000 to 10 meg-ohms that satisfactory performance is obtained with components in the pulse generator A, as follows: capacitor **23** is 2.0 microfarads; variable resistor **25** is from 100,000 to 700,000 ohms; resistor **27** is 920,000 ohms, and capacitor **26** is 6.0 microfarads.

The amplifier B, illustrated in FIGURE 2, has a light sensitive cell **37** positioned to be energized by illumina-

tion from neon lamp 33 when discharged. One side of the light sensitive cell 37 is connected to power line L_1 through resistor 38, half-wave rectifier 39, resistor 25 and half-wave rectifier 22. The other side of the light sensitive cell 37 is connected to power line L_2 through condenser 40. When dark, the light sensitive cell 37 has a very high resistance. However, when illuminated by the glow of neon lamp 33, its resistance is greatly reduced and completes a circuit from L_1 to L_2, as given above.

Resistor 38 protects the rectifier 39 against damage by surges of current which occur in the circuit the moment light sensitive cell 37 is activated. When the circuit is completed through light sensitive cell 37, the condenser 40 permits a momentary surge of current until it accumulates a charge. During this time the condenser, in effect, shorts the circuit which may damage the rectifiers, unless they are suitably protected.

By way of illustration, and not as a limitation of the invention, it has been found that satisfactory performance is obtained with component values in the amplifier B as follows: condenser 40 is 6.0 microfarads and resistor 38 is 650 ohms.

The pulses amplified by B are fed to filter network C which integrates the pulses. The output of the filter network is measured by ammeter D.

By way of illustration, and not as a limitation of the invention, the filter network may include components, as follows: variable resistor 36 is from 0 to 500,000 ohms, resistors 47–49 each is 150,000 ohms, condenser 41 is 2.0 microfarads, condenser 42 is 1.0 microfarad, condenser 43 is 0.5 microfarad, and condenser 44 is 0.25 microfarad.

Referring now to the operation of the apparatus the moving stream of material M which has dried by an oven 13 contacts the electrodes 20, 21. The rectifier 22 charges the capacitor 23 through resistor 25 over a time interval determined by well known resistor-capacitor principles. The capacitor 23 will attain a voltage after a period of time sufficiently high to discharge through the neon tube 33. When tube 33 fires, the capacitor 23 is not discharged completely, but only down to about two-thirds of its fully charged value. The capacitor is charged again, the time of the charge depending upon the size of resistor 25 and the electrical resistance between 20, 21, after which it is again discharged by tube 33. The repeated charge and discharge of capacitor 23 produces pulses which are picked up by amplifier B. If no material contacts electrodes 20, 21 the resistance therebetween is infinite and the shortest time will occur for the charge of capacitor 23, and the frequency of A is maximum. On the other hand, if electrodes 20, 21 contact damp or wet material, the capacitor is discharged therethrough so that the rate of charge of the capacitor 23 is reduced and the frequency of A is lowered.

Thus, the rate of charge and discharge of capacitor 23 is in proportion to the electrical resistance, and hence, the moisture content, of the material M contacted by electrodes 20, 22.

The electrical pulses of A generated by the charge and discharge of capacitor 23 are picked up by the light sensitive cell 37 in amplifier B and then fed to filter network C which integrates the pulses. The resultant current is indicated by ammeter 50.

Ammeter 50 may be calibrated to indicate a selected level of dryness, or moisture content. In ordinary practice it is sometimes desirable to adjust the system so that the desired moisture content will register at the center of the scale of meter 50. Any deviation therefrom will show whether the material is more, or less, dry than the desired standard.

The frequency of A is changed by varying the variable resistor 25. The apparatus is calibrated by placing material of the desired dryness against the electrodes 20, 21 and then varying resistors 25, 46 until the pointer of ammeter 50 is positioned at the proper mark.

If the system is employed in connection with a drying apparatus, as shown in FIGURE 1, the frequency period is preferably of sufficient length for random pieces of material M to contact electrodes 20, 21. In this way accurate regulation can be obtained, since the control is related to a large sample.

By way of illustration, and not as a limitation on the invention, and employing the components in FIGURE 2 as set forth hereinabove, the resistor 25 is adjusted so that the neon tube 33 flashes at about one cycle per second, with the calibrated resistance, or material of the desired moisture content across electrodes 20, 22. The variable resistor 46 is then adjusted to center the pointer of ammeter 50 at the calibrated mark on the scale after which the tube 33 will flash something different than one cycle per second. If the electrodes 20, 22 are now placed against material of different dryness, the meter 50 will deviate from the calibrated mark to indicate a greater, or less moisture content.

In the drawing and specification there has been set forth a preferred embodiment of the invention, and although specific terms are employed, these are used in a generic and descriptive sense only, and not for purposes of limitation. Changes in form and the proportion of parts, as well as the substitution of equivalents are contemplated, as circumstances may suggest or render expedient, without departing from the spirit or scope of this invention as further defined in the following claims.

What is claimed is:

1. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material contacting said electrodes to measure the electrical resistance of such material, pulse generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is discharged for producing electrical pulses and controlled by the electrical resistance of the material contacting said electrodes for varying the frequency rate of the pulses substantially proportional to the electrical resistance between said electrodes, and means responsive to the frequency rate of the pulses produced by said pulse generating means for producing a signal indicative of the moisture content of the material.

2. In an apparatus for analyzing material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed contacting said electrodes to measure the electrical resistance of such material, pulse generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is discharged for producing electrical pulses and controlled by the electrical resistance of the material contacting said electrodes for varying the frequency rate of the pulses substantially proportional to the electrical resistance between said electrodes, and means responsive to the frequency rate of the pulses produced by said pulse generating means for producing a signal indicative of the electrical resistance of the material.

3. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed engaging said electrodes to measure the electrical resistance of such material, means for causing relative moving contacts between said material and said electrodes so that random pieces of the material contact said electrodes, pulse generating means for producing electrical pulses, said pulse generating means controlled by the electrical resistance of the material contacting said electrodes for varying the frequency rate of the pulses substantially proportional to the electrical resistance between said electrodes, and means responsive to the frequency rate of the

pulses adapted to control the moisture content of the material.

4. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed engaging said elecrodes to measure the electrical resistance of material contacting said electrodes, frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is intermittently discharged for producing an electrical frequency output, said frequency generating means controlled by the electrical resistance of the material between said electrodes for varying the frequency rate of the electrical output substantially proportional to the electrical resistance between said electrodes, and means responsive to the frequency rate of the electrical output produced by said frequency generating means for producing a signal indicative of the moisture content of the material.

5. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed contacting said electrodes to measure the electrical resistance of such material, and frequency generating means controlled by the electrical resistance across said electrodes for producing a standard frequency rate output when said electrodes are contacted by material of preselected electrical resistance and for changing the frequency rate output from said standard frequency rate output responsive to the electrical resistance of the material contacting said electrodes which deviates from said preselected electrical resistance, said frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is intermittently discharged.

6. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed engaging said electrodes to measure the electrical resistance of such material, frequency generating means controlled by the electrical resistance across said electrodes for producing a standard frequency rate output when said electrodes are contacted by material of a preselected electrical resistance and for changing the frequency rate output from said standard frequency rate output responsive to the electrical resistance of the material contacting said electrodes which deviates from said preselected electrical resistance, said frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is intermittently discharged, and means responsive to said frequency rate output of said frequency generating means for producing a signal indicative of the moisture content of the material.

7. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed contacting said electrodes to measure the electrical resistance of such material, frequency generating means controlled by the electrical resistance across said electrodes for producing a standard frequency rate output when said electrodes are contacted by material of a preselected electrical resistance and for changing the frequency rate output from said standard frequency rate output responsive when the electrical resistance of the material contacting said electrodes deviates from said preselected electrical resistance, said frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is intermittently discharged, and means for integrating the frequency output produced by said frequency generating means.

8. In an apparatus for analyzing the moisture content of material, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material to be analyzed contacting said electrodes to measure the electrical resistance of such material, frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is discharged for producing a periodic electrical signal at a predetermined frequency rate output when said electrodes contact the material at the desired degree of electrical resistance and for varying the frequency rate output responsive to material which deviates from the desired degree of electrical resistance, and means responsive to the frequency rate of the signal for producing a direct current signal indicative of the moisture content of the material.

9. In an apparatus for analyzing the moisture content of material, support means for the material to be analyzed, electrodes spaced apart a fixed distance adapted to electrically contact the material to be analyzed for conducting electrical current through the material engaging said electrodes to measure the electrical resistance of such material, frequency generating means controlled by the electrical resistance across said electrodes for producing a periodic electrical signal and for varying the frequency rate of the electrical signal responsive to the electrical resistance of the material contacting said electrodes, said frequency generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is discharged, and means responsive to the frequency rate of the signal produced by said frequency generating means for producing a direct current signal indicative of the moisture content of the material.

10. In an apparatus for analyzing the moisture content of material, at least one pair of electrodes spaced apart a fixed distance positioned for contacting and completing an electrical circuit through the material to be analyzed for conducting an electrical current through the circuit completed by the material contacting said electrodes, generating means including a discharge means having a normally effectively infinite electrical resistance through which a predetermined charge is discharged for producing an electrical carrier frequency, said generating means controlled by the current flow between said electrodes for frequency modulating of the carrier frequency in relation to the amount of current flow between said electrodes.

11. In an apparatus for analyzing material, spaced electrodes adapted to electrically engage the material to be analyzed contacting said electrodes; oscillator means including an electrical charging circuit means and discharging circuit means communicating with said charging circuit means for a intermittent discharge of said charging circuit means through said discharging circuit means, said discharging circuit means having a normally nonconductive condition, said charging circuit means providing a time constant which is the function of the electrical resistance between said electrodes for controlling the frequency of said intermittent discharge responsive to the electrical resistance of the material engaging said electrodes, and frequency sensing means responsive to the frequency of said oscillator means for providing an output indicative of the electrical resistance of the material.

12. The apparatus of claim 11 in which said oscillator means includes means for variably presetting said time constant.

13. The apparatus of claim 11 wherein said discharge circuit means comprises a gaseous discharge tube.

14. The apparatus of claim 11 wherein said frequency sensing means is adapted to control the moisture content of the material.

15. The apparatus of claim 11 further including means for moving the material relative to the electrodes so as to obtain a sampling of the material contacting said electrodes.

16. The apparatus of claim 10 further characterized by means responsive to the modulation of carrier frequency for producing a signal indicative of the electrical resistance of the material.

17. The apparatus of claim 11 wherein said frequency sensing means includes means for producing an electrical signal in response to each said discharge of said charging circuit, and means for integrating said electrical signals.

18. The apparatus of claim 11 in which said discharging circuit means has a normally effectively infinite electrical resistance through which said charging circuit means is intermittently discharged.

19. In an apparatus for analyzing material:

an oscillator circuit generating an electrical oscillation which varies in frequency with variations in the electrical resistance of the material being analyzed and includes:

a direct current voltage source, a resistor and a capacitor connected in series, a discharge device, and spaced electrodes connected in parallel with said capacitor,

said discharge device normally having an infinite impedance and being adapted to intermittently discharge said capacitor when the voltage across said capacitor rises to a predetermined level,

said spaced electrodes being adapted to electrically engage the material to be analyzed contacting said electrodes,

said discharge device and the electrical resistance between said electrodes providing the sole discharge paths for said capacitor.

and frequency sensing means responsive to the frequency of said oscillator means providing an output indicative of the electrical resistance of the material.

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D. A. TAMBURRO, *Assistant Examiner.*