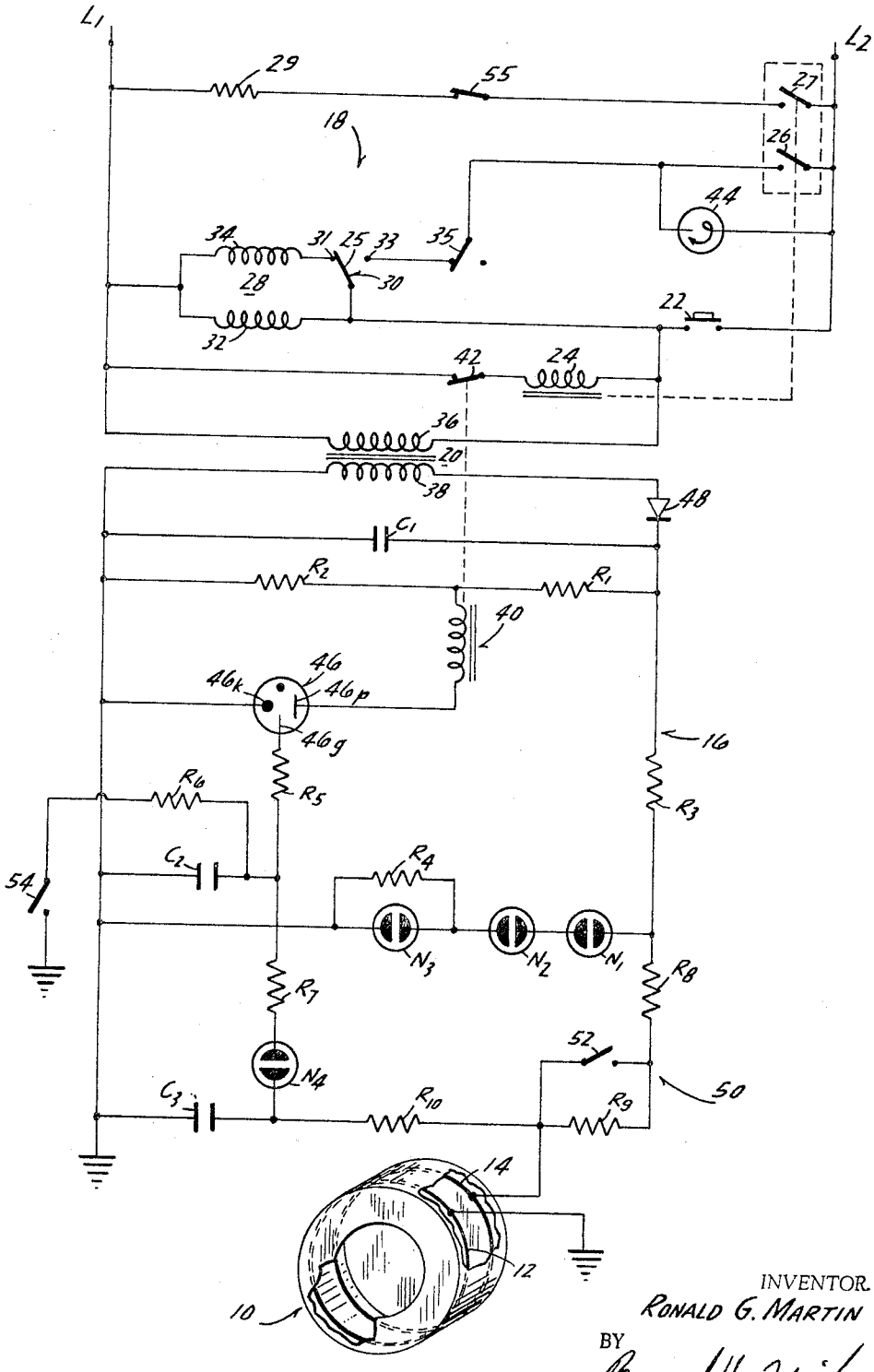
Sept. 13, 1966 R. G. MARTIN 3,271,878

MOISTURE SENSING CONTROL

Filed Oct. 14, 1963



INVENTOR.
RONALD G. MARTIN
BY
Raymond H. Michael
ATTORNEY.

United States Patent Office 3,271,878 Patented Sept. 13, 1966

3,271,878

MOISTURE SENSING CONTROL

Ronald G. Martin, Chicago, Ill., assignor to Controls Company of America, Melrose Park, Ill., a corporation of Delaware

Filed Oct. 14, 1963, Ser. No. 315,934
20 Claims. (Cl. 34—45)

This invention relates to dryer controls of the direct moisture sensing type.

Such controls operate on the basis of direct sensing of moisture content by monitoring the resistance of the material being dried which will vary in accordance with the moisture content of the material. The control senses to a predetermined moisture content at which point it shuts down the dryer, either directly or with an intervening cool-down cycle, or alternatively can be used to initiate a timed drying cycle after the direct sensing cycle. Examples of dryer controls of this type can be found in the following U.S. patent applications which are assigned to the assignee of this application: Dale F. Willcox application for "Dryer Control," Serial No. 31,922, filed May 26, 1960, now abandoned; Otto H. Behrens application for "Control Device," Serial No. 45,329, filed July 26, 1960; and Robert F. Guenther, Jr., and Ronald G. Martin for "Control Device and Timer," Serial No. 243,001, filed December 7, 1962.

A general object of this invention is to provide an improved version of this type of control.

A more specific object of this invention is to provide a direct moisture sensing control which achieves accurate control to low moisture contents with virtually no mechanical moving parts required thereby eliminating calibration problems generally encountered in mechanical-type controls and reducing the risk of failure.

Another object of this invention is to provide a completely electronic moisture sensing control which is effective to accurately control dryer operation to low values of moisture retention and compensate for drying mixed loads; and, furthermore, to reduce fluctuations in control operation due to variations in input voltage by providing regulation of the input voltage.

Other objects and advantages will be pointed out in, or be apparent from, the specification and claims, as will obvious modifications of the embodiment shown in the drawings which illustrates a portion of the circuit of a dryer including a moisture sensing control constructed in accordance with this invention.

With particular reference to the drawings, a dryer drum **10** is provided with a direct sensing mechanism which, in this instance, takes the form of a pair of sensing rings **12** and **14**. Sensing ring **12** is connected to ground and sensing ring **14** is connected in a control circuit in such a manner that a voltage is applied across the rings, this will be described more completely hereinafter. The sensing rings are arranged for contact with and to be bridged by the material being dried so that current leakage between the rings occurs through and in accordance with the moisture content of that material.

The electric circuit of the dryer can be considered in two parts, a moisture sensing and control portion **16** connected on the output side of transformer **20** and an operational portion **18** connected on the input side of the transformer.

Turning first to operational circuit **18**, leads L_1 and L_2 are connected to a suitable source (not shown) of alternating current and dryer operation is initiated through switch **22**. Operation of switch **22** completes a circuit to and energizes relay **24** to close relay switch **26** and complete a circuit to drive motor **28** of the dryer. Initially the circuit to motor **28** is completed through switch

22 and a centrifugal switch **30** so that both run winding **32** and start winding **34** are in circuit. When the motor comes up to speed, switch **30** operates to move switch blade **25** from contact **31** to contact **33** to complete a circuit to the motor through relay switch **26**, door switch **35** and contact **33** to thereby remove start winding **34** from the circuit.

It will be noted that primary winding **36** of transformer **20** is included in operational circuit **18** whereas secondary winding **38** is connected in sensing circuit **16** so that the output of the transformer is the source of electrical energy for the sensing circuit, with this arrangement transformer **20** also operates as an isolation transformer.

Heater **29** of the dryer is also activated upon energization of relay **24** through closure of relay switch **27**. Electrical heat supply means is illustrated merely by way of example and it will be appreciated that this invention is not limited to any particular type of heat supply means.

During dryer operation relay **40**, included in sensing circuit **16**, controls the state of energization of relay **24** to thereby control dryer operation, namely motor **28** and heater **29**. More particularly, switch **42** is connected to and operated by relay **40** and is included in circuit with relay **24** so that operation of relay **40** opens switch **42** to open the circuit to relay **24** and open switches **27** and **26** to de-energize both the dryer motor and heater. The state of energization of relay **40** is controlled by a thyratron **46** and, as will be discussed more completely hereinafter, thyratron **46** is initially, i.e. at the start of a drying cycle, in a non-conductive state so that the circuit to relay **40** is open but, when a predetermined moisture content of the material being dried is reached, it is rendered conductive to activate relay **40** and open switch **42** to de-energize relay **24**.

Thyratron **46** is included in electronic sensing circuit **16** and, as will become apparent from the following description, will be controlled in accordance with the condition of the material in dryer **10** as it contacts sensing rings **12** and **14**. More particularly, the output of transformer **20** is rectified by diode **48** so that direct current flows in the sensing circuit. The direct current passes through resistance R_3 and a selector **50** which includes resistances R_8 and R_9 and a selector switch **52** and is representative of control means which can be included to afford some choice in dryer operation. With the particular selector illustrated "DRY" or "DAMP DRY" operation can be selected, i.e open switch **52** to place both R_8 and R_9 in circuit to achieve a "DRY" operation or close the switch to remove R_9 for a "DAMP DRY" operation. Sensing ring **14** is connected in the sensing circuit and will have the direct current impressed thereon and, ring **12** being connected to ground, the potential across the rings will vary in accordance with the current leakage through the material being dried which will vary with the moisture content of the material, i.e. as the material dries the resistance thereof will increase and the potential on ring **14** will increase accordingly.

A neon lamp N_4 is connected in circuit with sensing ring **14** and between it and thyratron **46** to act as a switching device which is effective to periodically apply the charge on ring **14** to grid **46***g* of the thyratron. More particularly, neon lamp N_4 is normally non-conductive when dryer operation is initiated as its switch-over voltage is above the voltage which will appear on ring **14** at the start of the drying cycle due to the high rate of leakage which occurs through the material having a relatively high moisture content. Capacitor C_3 is also connected in the circuit with the neon lamp N_4 and sensing ring **14** and begins to charge to the value of the voltage on ring **14** and this charge increases until it reaches the switch-over voltage for lamp N_4 whereupon the lamp

breaks down and begins to conduct with capacitor C_3 discharging therethrough. Resistance R_{10} cooperates with capacitor C_3 to provide a filter network which reduces voltage spikes across the rings and prevents premature breakdown of lamp N_4 which may occur where a small or suspended load condition is present in the drum and an artificially high potential appears for a short time across the sensing rings. The charge on capacitor C_3 is dissipated through lamp N_4 and is applied to grid **46***g* of the thyratron.

Thyratron **46** exhibits a particular switch-over voltage at which it is rendered conductive and the switch-over voltage of N_4 is selected such that it is below the switch-over voltage of thyratron **46** so that the charge necessary on capacitor C_3 to breakdown lamp N_4 is insufficient to trigger the thyratron. A second capacitor C_2 is connected in the circuit between lamp N_4 and thyratron **46** and is characterized by having a charge storing capacity which is at least equal to the switch-over voltage of thyratron **46**. Thus, when lamp N_4 is initially rendered conductive the charge which passes through the lamp is insufficient to trigger the thyratron and is received and stored on capacitor C_2. The charge on capacitor C_3 is dissipated through lamp N_4 and will eventually diminish to a value below the maintaining voltage for lamp N_4 at which point the lamp will be extinguished and remain in a non-conductive state until a charge equal to its switch-over voltage is again accumulated on capacitor C_3. This periodic discharging of capacitor C_3 will continue until a charge corresponding to the switch-over voltage of thyratron **46** accumulates on capacitor C_2 whereupon the necessary voltage is impressed on grid **46***g* to initiate current flow between plate **46***p* and cathode **46***k* and complete a circuit through relay **40**. Switching thyratron **46** from non-conductive to conductive to achieve the control operation of relay **40** is preferred as it insures reliable, predictable and consistent operating characteristics from the relay. Resistance R_5 is provided in the grid circuit to maintain the current flow to the grid at a safe level.

In operation, when the dryer is initially energized, thyratron **46** is non-conductive and relay **40** is in an unactuated condition. Selector mechanism **50** will have been operated to select either a "DAMP DRY" or "DRY" operation. A D.C. voltage is applied to ring **14** and as the moisture content of the material in the dryer is reduced the potential across rings **14** and **12** increases and a charge accumulates on capacitor C_3. The charge on capacitor C_3 will eventually equal the breakdown voltage for lamp N_4 at which point the lamp is rendered conductive and capacitor C_3 discharges through the lamp. The switch-over voltage of lamp N_4 is below the switch-over voltage of thyratron **46** and this charge is ineffective to render the thyratron conductive and is received and stored by capacitor C_2. When the charge on capacitor C_3 diminishes below the maintaining voltage of lamp N_4, the lamp is extinguished without having rendered thyratron **46** conductive and the drying operation continues and the sensing control also continues to sense the moisture content of the material. Again a charge accumulates on capacitor C_3 in accordance with current leakage across rings **14** and **12** until that charge again reaches the breakdown voltage of lamp N_4 whereupon capacitor C_3 will again discharge through the lamp. Lamp N_4 is periodically rendered conductive until the charge on capacitor C_2 reaches the switch-over voltage of thyratron **46***g* when this condition is reached the thyratron is triggered and completes a circuit through relay **40**. Relay **40** opens switch **42** to de-energize relay **24** which in turn opens relay contacts **26** and **27** to de-energize the heater and motor. Capacitor C_2, together with resistance R_7, provides an RC time delay in the grid circuit of thyratron **46**.

Thus, a time delay between the initial discharge of neon lamp N_4 and operation of the thyratron to de-energize the heater is provided through a completely electronic arrangement. With this arrangement, the initial response of lamp N_4 can be selected to occur at a predetermined voltage corresponding to a particular, desired moisture content of the material being dried. But, before the thyratron is triggered, the lamp N_4 is extinguished and the direct sensing cycle of the sensing circuit is repeated. As set forth in the application of Dale F. Willcox, Serial No. 31,922, all fabrics, synthetic or natural, if initially at the same moisture content will dry in the same length of time so that if the fabrics are reduced to a uniform moisture content they can be reduced to a lower moisture content if desired by a straight timed cycle. The electronic time delay circuit can provide a timed cycle from the moisture content condition indicated by the initial discharge of lamp N_4 and by proper selection of the circuit elements (lamp N_4, capacitor C_2 and thyratron **46**) the desired time delay can be adjusted. However, an advantage in the electronic time delay circuit of this invention is that subsequent to initial discharge of the lamp, and during the time delay period, the sensing circuit is re-established so that direct sensing of the material is repeated and continues until the desired moisture content is reached. A control of this type provides continuing moisture sensing and automatic adjustment to or accommodation of mixed loads and, furthermore, will achieve accurate control to a moisture content range of 0 to 1%. Moreover, an additional advantage lies in the elimination of a mechanical timer thereby eliminating the problems of initial calibration, continued adjustment and possible mechanical failures.

To insure that capacitor C_2 is uncharged at the start of a drying cycle, the capacitor is connected to ground through a switch **54** which, when closed, discharges any residual capacitor charge to ground. For example, switch **54** can be controlled with, or be a part of, door switch **35** and when the dryer door is opened at the end of an operation any residual charge left on capacitor C_2 is discharged.

Sensing circuit **16** also includes a voltage regulating circuit to afford control over the voltage applied to sensing ring **14**. The regulating circuit includes neon lamps N_1, N_2 and N_3, and resistance R_4 across lamp N_3 to assist in starting that lamp. The operation of the regulating circuit shown is well known in the art and is purely illustrative as other circuit arrangements could be used equally well. In general terms the characteristics of this particular circuit are such that with an increase in input current and corresponding increase in current flow through lamps N_1, N_2 and N_3, the maintaining voltage of the lamps remains relatively constant so that the D.C. voltage between lamp N_1 and ground remains constant with variations in input voltage.

Among the features included in operational circuit **16**, and commonly included in a dryer, is to provide for a cool-down cycle at the termination of the drying cycle. More particularly, after thyratron **46** has been actuated and relay **24** operated, thermostatic switch **44** can be closed, in any suitable manner, to complete a circuit through motor **28** with heater **29** de-energized to continue dryer operation until a predetermined temperature is reached in the dryer drum. At this reduced temperature switch **44** opens the circuit to motor **28** to shut down the dryer. Another feature commonly incorporated in the dryer is an air fluff operation and to this end air fluff switch **55** is included in circuit with heater **29** and can be opened to remove heater **29** and permit the dryer to operate without heat.

Although but one embodiment of the present invention has been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

What I claim is:

1. A moisture sensing control for use with apparatus for drying material and operative to control the heat supply means of said apparatus in accordance with the moisture content of said material, said moisture sensing control comprising, in combination,

sensing means including an electrode arranged for engagement with said material,

means for applying a D.C. voltage to said electrode with the voltage thereon varying in accordance with current leakage through said material so that the voltage on said electrode increases as the moisture content of said material decreases,

switch means for controlling energization of said heat supply means and having a switch-over voltage at which its operational state is changed to de-energize said heat supply means,

a neon lamp connected in circuit between said electrode and said switch means and having a switch-over voltage at which it is rendered conductive and below which it is non-conductive, the switch-over voltage of said neon lamp being below that of said switch means and the voltage on said electrode at the initiation of the drying operation being below the switch-over voltage of said neon lamp so that said switch means is electrically isolated from said electrode and is in a first operational state,

capacitive means connected in circuit with said neon lamp and electrode for receiving and storing a charge from said electrode and characterized by having a capacity at least equal to the switch-over voltage of said neon lamp,

and capacitive means connected in circuit between said neon lamp and said switch means and characterized by having a capacity at least equal to the switch-over voltage of said switch means.

2. The moisture sensing control of claim 1 including an input transformer connected in circuit with said sensing means and means for rectifying the A.C. output of said transformer to D.C.

3. A moisture sensing control for use with apparatus for drying material and operative to control the heat supply means of said apparatus in accordance with the moisture content of said material, said moisture sensing control comprising, in combination,

sensing means arranged in said apparatus for engagement with said material,

means for applying a D.C. voltage to said sensing means with the voltage on said sensing means varying in accordance with current leakage through said material,

first normally non-conductive switch means for controlling operation of said heat supply means and characterized by having a predetermined switch-over voltage at which its operational state is changed,

second normally non-conducting switch means characterized by having a switch-over voltage below the switch-over voltage of said first switching means and a maintaining voltage at which it is conductive and below which it is non-conductive, said second normally non-conducting switch means connected in circuit with said sensing means and said first non-conducting switch means to normally electrically isolate said first non-conducting switch means from said sensing means,

charge storing means in circuit with said second switch means and said sensing means and characterized by having a charge storing capacity at least equal to the switch-over voltage of said second switch means so that a charge is stored on said charge storing means in response to the voltage build-up on said sensing means as the moisture content of said clothing is reduced until the switch-over voltage of said second switch means is reached whereupon said charge storing means discharges through said second switch means and falls below the maintaining voltage of said second switch means which is again rendered non-conductive,

and charge storing means in circuit with said first and second switch means and having a charge storing capacity at least equal to the switch-over voltage of said first switch means for receiving and storing the charge discharged through said second switch means until the switch-over voltage of said first switch means is reached whereupon said first switch means is rendered conductive to de-energize said heat supply means.

4. The moisture sensing control of claim 3 including voltage regulating means in circuit with and controlling the voltage applied to said sensing means to maintain a substantially uniform voltage thereon.

5. The moisture sensing control of claim 3 including means in circuit with and operative to vary the voltage applied to said sensing means.

6. The moisture sensing control of claim 3 wherein said apparatus includes a door switch connected in circuit with and operative to connect said charge storing means in circuit with said first and second switch means to ground and remove any residual charge thereon prior to initiation of operation of said apparatus.

7. A moisture sensing control for use with apparatus for varying the moisture content of material and comprising, in combination,

sensing means arranged in said apparatus for engagement with said material,

means for applying a voltage to said sensing means with the voltage on said sensing means varying in accordance with current leakage through said material,

first switch means characterized by having a predetermined switch-over voltage at which its operational state is changed and operative to effect a control function in said apparatus upon said change in operational state thereof,

first charge storing means in circuit with said first switch means and characterized by having a charge storing capacity at least equal to the switch-over voltage of said first switch means,

second charge storing means connected in circuit with said sensing means for response to the voltage thereon,

and second switch means in circuit with and normally electrically isolating said first and second charge storing means, said second switch means characterized by having a predetermined switch-over voltage and at which its operational state is changed to electrically connect said second charge storing means to said first charge storing means to transfer the charge on said second charge storing means to said first charge storing means, the switch-over voltage of said second switch means being below that of said first switch means.

8. The moisture sensing control of claim 7 wherein D.C. voltage is applied to said sensing means.

9. The moisture sensing control of claim 8 including voltage regulating means in circuit with and controlling the voltage applied to said sensing means to maintain a substantially uniform voltage thereon.

10. The moisture sensing control of claim 8 including means in circuit with and operative to vary the voltage applied to said sensing means.

11. The moisture sensing control of claim 8 including means operative to remove any residual charge from said first charge storing means prior to initiation of operation of said drying apparatus.

12. A moisture sensing control for use with apparatus for varying the moisture content of material and comprising, in combination,

sensing means arranged in said apparatus for engagement with said material,

means for applying a voltage to said sensing means with

the voltage on said sensing means varying in accordance with current leakage through said material,

first switch means characterized by having a predetermined switch-over voltage at which its operational state is changed,

charge storing means in circuit with said first switch means and having a charge storing capacity at least equal to the switch-over voltage of said first switch means,

and transfer means responsive to the voltage on said sensing means and connected in circuit with and normally electrically isolating said sensing means and said first switch means, said transfer means operative to periodically respond to a predetermined voltage on said sensing means and electrically connect said sensing means to said first switch means and apply said predetermined voltage to said first switch means, said predetermined voltage being below said switch-over voltage so that said charge storing means is charged until the switch-over voltage of said first switch means is reached whereupon the operational state of said first switch means is changed to provide a control signal to effect a control function in said apparatus.

13. The moisture sensing control of claim **12** wherein said transfer means includes normally non-conducting switch means and time delay means in circuit between said sensing means and said normally non-conducting switch means and operative to store a charge and provide a delay in the response of said normally non-conducting switch means to the voltage on said sensing means and periodically rendering said non-conducting switch means conductive to transfer the charge from said time delay means to said charge storing means.

14. A moisture sensing control for use with apparatus for varying the moisture content of material and comprising, in combination,

sensing means arranged in said apparatus for engagement with said material,

means for applying a voltage to said sensing means with the voltage on said sensing means varying in accordance with current leakage through said material,

first switch means characterized by having a predetermined switch-over voltage at which its operational state is changed and operative to effect a control function in said apparatus upon the change in operational state thereof,

second normally non-conducting switch means in circuit with and normally electrically isolating said sensing means from said first switch means and characterized by having a switch-over voltage below the switch-over voltage of said first switch means so that said second switch means is responsive to the voltage on said sensing means,

and electrical time delay means having a charge storing capacity at least equal to the switch-over voltage of said first switch means and connected in circuit between said second switch means and said first switch means for receiving and storing an electrical charge conducted through said second switch means until the charge accumulated is at least equal to the switch-over voltage of said first switch means.

15. The moisture sensing control of claim **14** including means in circuit with said sensing means and said normally non-conducting switch means for providing a delay in the response of said normally non-conducting switch means to the voltage on said sensing means.

16. The moisture sensing control of claim **15** wherein a D.C. voltage is applied to said sensing means.

17. A moisture sensing control for use with apparatus for drying material and operative to control the heat supply means of said apparatus in accordance with the moisture content of said material, said moisture sensing control comprising, in combination,

sensing means adapted to have a voltage applied thereto and arranged for engagement with said material with the voltage on said sensing means varying in accordance with the current leakage through said material,

means for applying a D.C. voltage to said sensing means,

switch means connected with said heat supply means and having a switch-over voltage at which its operational state is changed to control energization of said heat supply means,

transfer means connected in circuit between and normally electrically isolating said switch means from said sensing means, said transfer means being responsive to the voltage on said sensing means to electrically connect said sensing means to said switch means, said transfer means responding to a voltage below said switch-over voltage,

and electrical timing means connected in circuit between said switch means and said transfer means for receiving and storing a charge until the accumulated charge thereon is at least equal to said switch-over voltage so that a change in operational state of said switch means and de-energization of said heat supply means is effected with a predetermined time delay.

18. The moisture sensing control of claim **17** wherein said electrical timing means comprises an RC time delay network.

19. A moisture sensing control for use with apparatus for drying material and operative to control the heat supply means thereof in accordance with the moisture content of said material, said moisture sensing control comprising, in combination,

first switch means in circuit with and controlling said heat supply means,

relay means connected to and controlling said first switch means,

second switch means connected to and controlling said relay means and having a switch-over voltage at which its operational state is changed to change the operational state of said relay means and de-energize said heat supply means,

sensing means adapted to have a voltage applied thereto and arranged for engagement with said material with the voltage on said sensing means varying in accordance with the current leakage through said material,

means for applying a D.C. voltage to said sensing means,

transfer means responsive to the voltage on said sensing means and connected in circuit between and normally electrically isolating said second switch means from said sensing means, said transfer means operative to respond to a predetermined voltage on said sensing means and electrically connect said sensing means to said second switch means and apply said predetermined voltage to said second switch means, said predetermined voltage being below said switch-over voltage,

and electrical timing means connected in circuit between said second switch means and said transfer means for receiving and storing a charge until the accumulated charge thereon is at least equal to the switch-over voltage of said second switch means so that a change in the operational state of said second switch means and de-energization of said heat supply means is effected with a predetermined time delay.

20. A moisture sensing control for use with apparatus for drying material and operative to control the heat supply means thereof in accordance with the moisture content of said material, said moisture sensing control comprising, in combination,

first switch means in circuit with and controlling said heat supply means,

relay means connected to and controlling said first switch means,

second switch means connected to and controlling said relay means and having a switch-over voltage at which its operational state is changed to change the operational state of said relay means and de-energize said heat supply means,

sensing means adapted to have a voltage applied thereto and arranged for engagement with said material with the voltage on said sensing means varying in accordance with the current leakage through said material,

means for applying a D.C. voltage to said sensing means,

transfer means connected in circuit between and normally electrically isolating said second switch means from said sensing means, said transfer means including normally non-conducting switch means having a switch-over voltage below that of said second switch means and charge storing means connected between said non-conducting switch means and said sensing means, said transfer means operative to periodically transfer an electrical charge from said sensing means to said second switch means with said charge being below said switch-over voltage,

and electrical timing means connected in circuit between said second switch means and said transfer means and including capacitive means connected between said second switch means and said non-conducting switch means and having a charge storing capacity at least equal to the switch-over voltage of said second switch means so that a change in the operational state of said second switch means and de-energization of said heat supply means is effected with a predetermined time delay.

References Cited by the Examiner

UNITED STATES PATENTS

3,180,038	4/1965	Chafee	34—45
3,197,884	8/1965	Smith	34—45

FREDERICK L. MATTESON, JR., *Primary Examiner.*

WILLIAM F. O'DEA, *Examiner.*

D. A. TAMBURRO, *Assistant Examiner.*