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ELECTRONIC DRYER CIRCUIT WITH PULSED SENSING MEANS

Filed June 27, 1966

3 Sheets-Sheet 1

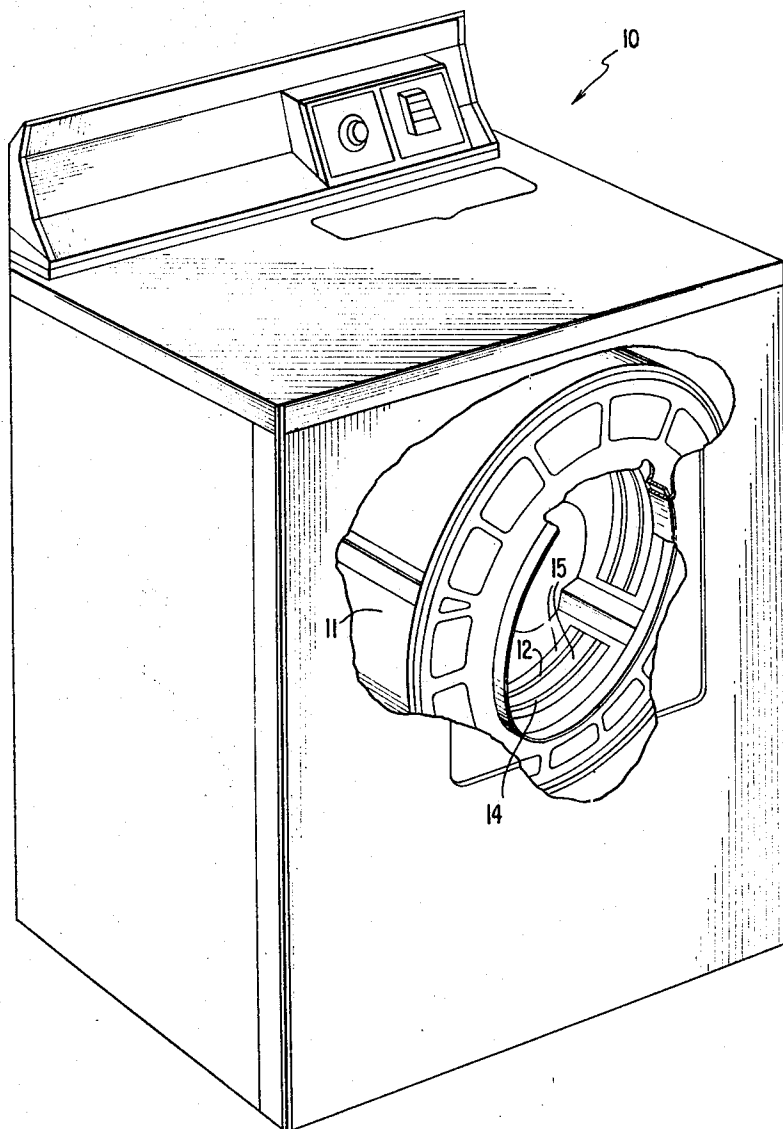


FIG. 1

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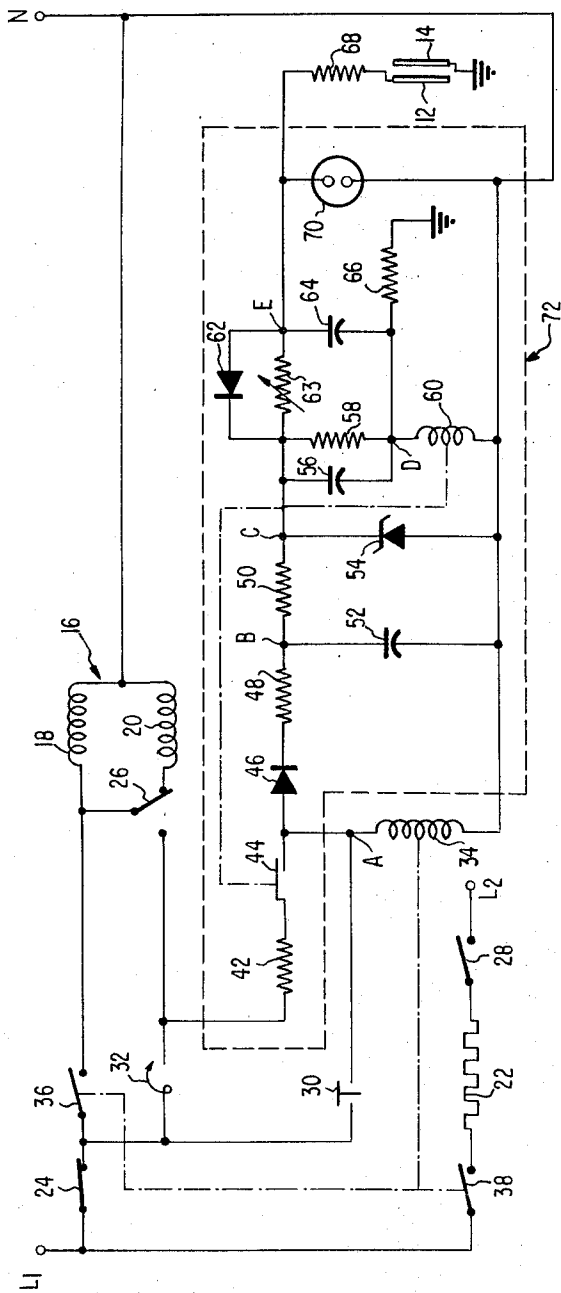


FIG. 2

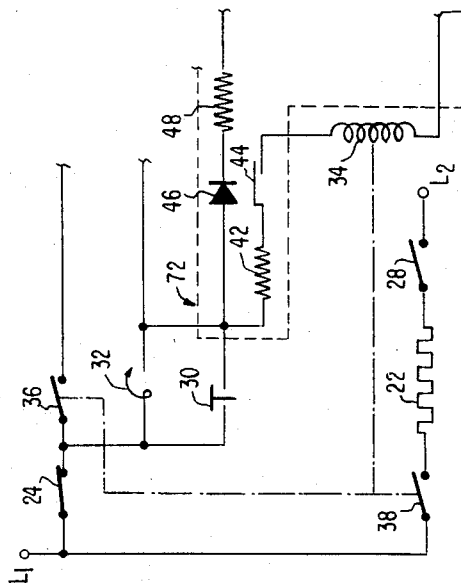


FIG. 3

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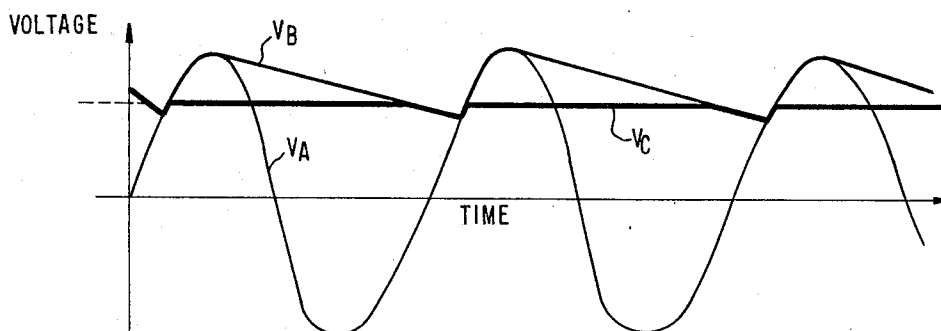
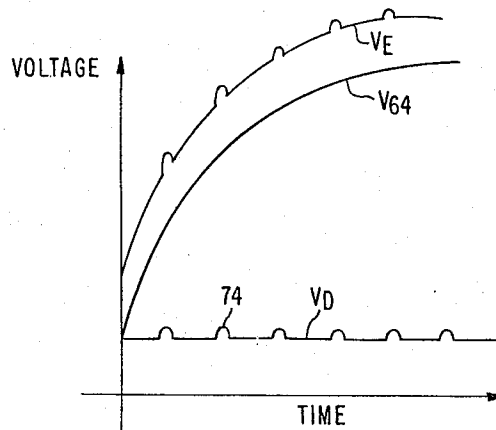
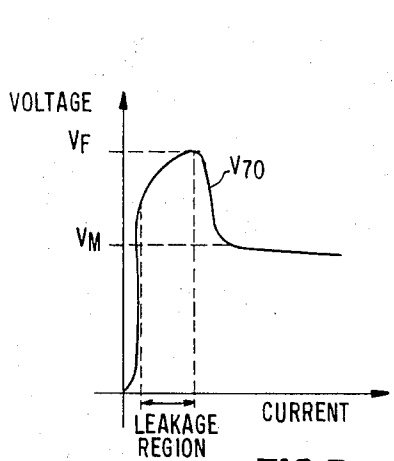
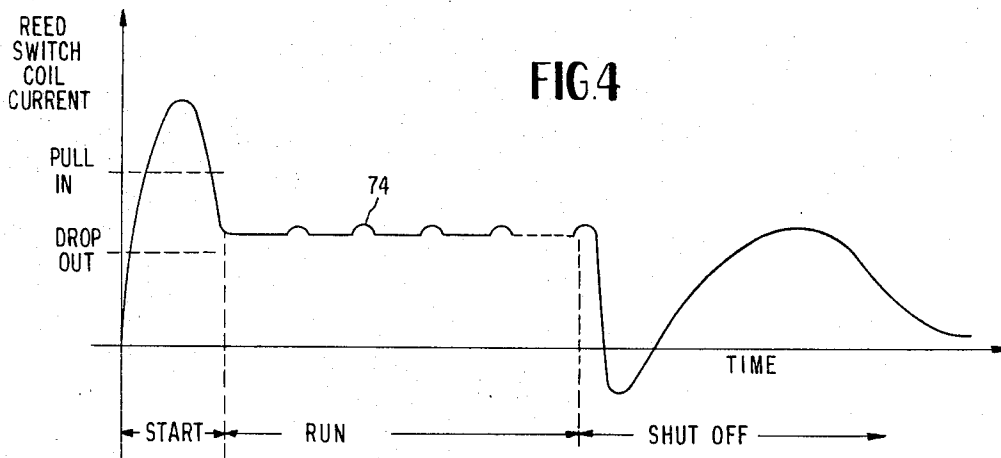
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3 Sheets-Sheet 3



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ELECTRONIC DRYER CIRCUIT WITH PULSED SENSING MEANS

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ABSTRACT OF THE DISCLOSURE

A clothes dryer control circuit in which a DC signal containing an AC ripple energizes a relay coil whose closed contacts maintain the dryer in operation. The same signal is also supplied to the parallel combination of a storage capacitor and a resistance whose value is inversely proportional to the moisture content of the clothes. When the clothes are wet the capacitor cannot charge due to the low value of the resistance. When the clothes become dry, however, the capacitor begins to charge and its level is sensed by a threshold device sampled by the AC ripple. When the threshold device is triggered the capacitor is discharged through the relay coil in opposition to its holding current, thereby de-energizing the coil and terminating the dryer operation.

This invention relates in general to an electronic control circuit for a fabric conditioning apparatus, and more particularly to a novel clothes dryer control circuit featuring pulse sampled threshold sensing means for ensuring proper operation.

For many years the accepted method of terminating clothes dryer cycles was by means of mechanical timers. Although in most cases the timers could be pre-set to selected cycle lengths, such selection was a somewhat arbitrary one based primarily on the operator's experience. As a result, most drying cycles were terminated either too soon or too late, with remnant dampness or excessive shrinkage the undesirable consequences.

More recently it has been proposed to effect drying cycle termination through the use of control means responsive to the moisture content of the fabrics being treated, thus assuring shutdown at the optimum time to both prolong fabric life and avoid power waste. In one prior art dryer control circuit a charging current is supplied to the parallel combination of a storage capacitor and a moisture sensing means, the latter consisting of a series of spaced conductive bands located on the inner surface of the dryer drum. When the clothes being treated are moist, they complete a circuit path between the bands and shunt the charging current to ground. As the clothes become drier their electrical resistance increases and a charge begins to build up on the capacitor. The magnitude of this charge is sensed by a threshold device in the form of a glow tube and, when the capacitor charge reaches a sufficient level, the tube fires and terminates the drying cycle.

Unfortunately, most voltage threshold sensing devices, including glow tubes and neon lamps, exhibit considerable inherent leakage current at voltage levels just below their firing potentials. As a result of this characteristic, a danger exists in the prior art circuit just described that as the capacitor charge approaches the firing potential of the threshold sensor, the leakage current through the latter will increase to such an extent that the capacitor will never charge up to the firing potential level. Under these conditions the threshold device will never fire and the machine will enter into an endless drying cycle.

It is therefore a primary object of this invention to pro-

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vide a control circuit for a fabric drying apparatus which overcomes the above and other disadvantages of the prior art systems by employing a pulse sampling technique to ensure proper operation.

It is a further object of this invention to provide such a control circuit which includes voltage regulating means to obviate the effects of power source fluctuations, and in which the voltage regulating means inherently produces cyclic ripples that are converted to voltage pulses and utilized to advantage in implementing the sampling technique.

It is a further object of this invention to provide such a control circuit which includes coil operated switch means to effect control of the operation of the clothes dryer and in which an initial current transient closes the coil operated switch means to commence the drying cycle, a holding current in one direction through the switch coil maintains the switch means closed throughout the drying cycle and a current flow through the switch coil opposite to the holding current substantially reduces the effective current through the coil to open the switch means and terminate the drying cycle when the dryness of the clothing has reached a pre-selected level.

It is a further object of this invention to provide such a control circuit in which the switch means may be connected in parallel with the voltage regulating means whereby the opening of the switch means does not interrupt the availability of regulated voltage for other machine functions.

Briefly, according to the invention a regulated DC voltage containing cyclic ripples is supplied to the operating circuit of a reed switch coil. The operating circuit contains a capacitor which converts the ripples into voltage pulses and superimposes them on the DC voltage being applied to the coil. The regulated signal is also supplied to the parallel combination of the storage capacitor and a moisture responsive resistance, the storage capacitor being connected in series with the reed switch coil. Parallel electrodes or conductive bands are spaced from each other and disposed on the inner surface of a dryer drum. The damp clothing in the drum lays against the bands and bridges the space between them, thus providing an electrical resistance which is a function of the moisture content of the clothing. The regulated current is initially shunted to ground through the clothing. As they become drier and their resistance increases, however, a charge begins to build up on the storage capacitor. The magnitude of this charge is sensed by a neon lamp connected across the storage capacitor and the reed switch coil, so that the lamp actually sees the combined voltages across the capacitor and the coil. Since the coil voltage contains cyclic pulses the lamp is thus effectively sampled at the cycle frequency rate at the pulses drive the lamp voltage up and down along its characteristic curve. As the voltage across the capacitor increases the lamp will be driven in and out of its current leakage region by the pulses, but since their duration is relatively short compared with the cycle time, the net leakage will be small and the capacitor will continue to charge. When the clothes are completely dry and the charge on the capacitor has reached a sufficient level, one of the pulses will drive the lamp voltage above the firing potential and the lamp will ionize. The capacitor will then discharge through the lamp and the reed switch coil. The discharge current through the coil is in opposition to its holding current which results in a net current in the coil that is substantially below the reed switch drop out level and thereby ensures a positive opening of the reed switch. This initiates a chain of circuit operations that terminate the drying cycle.

The foregoing and other objects, features and advan-

tages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings, in which:

FIGURE 1 shows a perspective view of a clothes dryer including a cut-away portion for illustrating the mounting arrangement for the conductive bands,

FIGURE 2 shows a schematic diagram of a dryer control circuit constructed in accordance with the teachings of this invention,

FIGURE 3 shows a schematic diagram of a modification of a portion of the circuit shown in FIGURE 2,

FIGURE 4 shows a time plot of the current waveform in the reed switch coil,

FIGURE 5 shows the voltage versus current characteristic of the neon lamp, and

FIGURES 6 and 7 show time plots of the voltage waveforms at selected points in the circuit of FIGURE 2.

As may be seen in FIGURE 1, a clothes dryer 10 according to this invention includes a rotating drum 11 having at least two electrically conductive bands 12 and 14 mounted therein parallel to each other and spaced apart on an insulating pad 15, the latter being secured to the inner surface of the drum.

Referring now to FIGURES 2 and 3, rather than unduly burden this specification with a detailed and lengthy description of the interconnections between each circuit element shown, which are believed to be obvious from the face of the drawings, such elements are instead simply listed below along with the corresponding reference numerals used throughout the drawings to designate them.

- 12, 14—conductive bands (electrodes)
- 16—dryer motor
- 18—run winding
- 20—start winding
- 22—heating element
- 24—door operated switch
- 26, 28—motor operated centrifugal switches
- 30—spring biased start switch (normally open)
- 32—thermostatic switch (opens on cooling)
- 34—relay coil
- 36, 38—relay operated switches (normally open)
- 42—limiting resistor
- 44—reed switch
- 46—diode rectifier
- 48, 50—resistors
- 52—filter capacitor
- 54—Zener diode
- 56—differentiating capacitor
- 58—resistor
- 60—reed switch coil
- 62—diode
- 63—variable resistor
- 64—storage capacitor
- 66, 68—limiting resistors
- 70—neon lamp
- 72—electronic control section

Turning now to the operation of the dryer circuit shown in FIGURE 2, which will be explained in conjunction with the voltage and current waveforms shown in FIGURES 4-7, 220-volt, 60-cycle power is supplied to the system at terminals L1, L2 and N, the latter being neutral or ground. Assuming that wet clothes have been loaded into the dryer drum and that door switch 24 has been closed by the closing of the dryer door, the depression of start switch 30 causes the sinusoidal waveform V_A shown in FIGURE 7 to appear at point A. This waveform energizes relay coil 34 which closes its associated switches 36 and 38. The closing of switch 36 supplies power to both run winding 18 and start winding 20 of dryer motor 16. When the motor comes up to speed, centrifugal switch 26 transfers to its other position and centrifugal switch 28 closes. The transfer of switch 26

de-energizes the start winding 20 while the closing of switch 28 completes the circuit path through heating element 22 and previously closed switch 38, and the heating element is thus energized by the full 220 volt line voltage appearing across terminals L1 and L2. It is to be understood that while an electric heating element has been disclosed, this invention is equally applicable to any type of drying apparatus, and element 22 could be replaced by an electrically operated valve in the case of a gas dryer.

When the start switch 30 is depressed, the alternating signal at point A also enters the electronic control section 72. This signal is half-wave rectified by diode 46 and smoothed by the filter network comprising resistor 48 and capacitor 52, with the resulting DC waveform at point B shown as V_B in FIGURE 7. This waveform is applied through resistor 50 to Zener diode 54, which performs a regulating function by reason of its reverse breakdown characteristic to produce waveform V_C in FIGURE 7 at point C. It will be noted that the voltage V_C is not a straight line function, but contains a small negative ripple during each cycle.

The initial transient created at point C by the depression of the start switch surges through capacitor 56 and the impedance afforded by coil 60. As seen in FIGURE 4, the magnitude of this transient current exceeds the pull-in threshold and reed switch 44 closes. As capacitor 52 stabilizes, the transient decays. The DC signal at point C is blocked by capacitor 56, but resistor 58 passes sufficient holding current to maintain the reed switch in its closed position, as shown by the "run" portion of the curve in FIGURE 4. Capacitor 56, however, does pass the cyclic ripples in waveform V_C and superimposes them on the DC signal supplied by resistor 58, thereby resulting in waveform V_D of FIGURE 6 at point D. Since the reed switch 44 is connected in parallel with the start switch 30 through centrifugal switch 26, it acts as a holding circuit when closed, and all of the circuit elements continue in operation when the start switch is released. When the dryer temperature reaches a sufficient level, thermostatic switch 32 closes, which provides an alternate line signal path through motor 16 and electronic control section 72. Closed reed switches exhibit very low contact resistance and because of this, limiting resistor 42 is connected in series with reed switch 44 to preclude the possibility of motor 16 being supplied current through the circuit which includes reed switch 44.

The DC signal at point C is also applied through variable resistor 63 to storage capacitor 64, neon lamp 70 and conductive band 12. As long as the clothing in the dryer drum is wet the current available at point E is shunted to ground across bands 12 and 14 through the low resistance path offered by the clothing. As the clothing becomes drier, however, its resistance increases and a charge gradually builds up on capacitor 64, as shown by curve V_{64} in FIGURE 6. The charging rate of the capacitor may be controlled by the adjustment of variable resistor 63. The voltage impressed upon neon lamp 70, which sees the combined voltages across storage capacitor 64 and reed switch coil 60, also begins to increase as shown by curve V_E in FIGURE 6. This curve represents the summation of curves V_D and V_{64} .

As the lamp voltage increases, the current leakage region is approached, as shown in the characteristic curve of the lamp in FIGURE 5. If the lamp was gradually driven into the leakage region by monitoring only the voltage across storage capacitor 64, a distinct possibility exists that the leakage current would be sufficient to prevent the capacitor from ever charging above the firing potential V_F . In this event the dryer would enter an undesirable endless run cycle.

Since the lamp 70 in the instant circuit sees the cyclic pulse signals 74, as well, however, whose magnitudes are greater than the difference between V_F and V_M in FIGURE 5, the lamp voltage is only driven into the leakage

region during the brief sampling times afforded by the pulses. As a result, the current leakage is minimized and the storage capacitor 64 continues to charge during the relatively long intervals between the pulses.

When the clothes become dry and the capacitor charge builds up to a sufficient level, one of the sampling pulse signals 74 drives the lamp voltage above the firing threshold V_F and the lamp ionizes. Capacitor 64 then discharges through the lamp and the reed switch coil 60. The discharge current through the coil is in a direction opposite to that of the holding current through resistor 58 which substantially reduces the net current through the coil. In one embodiment the magnitude of the discharge current was sufficient to cause a complete polarity reversal across the coil, as shown by the initial "shut-off" portion of the curve in FIGURE 4. Reed switch 44 then opens, which de-energizes both the relay coil 34 and the electronic control section 72. When coil 34 is de-energized, its associated switches 36 and 38 return to their open positions. The opening of switch 38 de-energizes the heating element 22, but the opening of switch 36 has no immediate effect since the run winding 18 of the dryer motor 16 is still supplied through the closed thermostatic switch 32 and the transferred centrifugal switch 26. When the dryer cools down sufficiently thermostatic switch 32 opens and motor 16 is de-energized, thus terminating the entire drying cycle.

When the capacitor 64 discharges to the point where the voltage at point E is below the conduction maintaining potential of the lamp V_M the lamp extinguishes and reverts to its non-conductive state. By this time the reed switch 44 has already opened, however, and the decaying voltage at point C soon reaches a lower level than that at point E. When this happens the diode 62, which was reverse biased during the entire start and run cycles, becomes forward biased and any charge remaining on one side of the capacitor 64 is immediately passed to the opposite side through the diode 62 and resistor 58. This prevents an operator from receiving an electrical shock if he touches the conductive band 12 while unloading the clothes from the dryer. As an additional safety feature, resistors 66 and 68 are incorporated into the circuit as shown to limit any current with which an operator might come into contact.

In the modified portion of the circuit shown in FIGURE 3, reed switch 44 is connected in series only with relay coil 34 rather than in series with both the relay coil 34 and control section 72 as is the case in FIGURE 2. The effect of this change is that when reed switch 44 opens in response to the lamp ionization and deenergizes relay coil 34, regulated DC power is still available at point C within electronic control section 72, until thermostatic switch 32 opens. Since capacitor 52 is stable, no initial transient surge is again developed through capacitor 56 and reed switch coil 60. Therefore, the reed switch contacts will remain open, and, although the control section 72 is still energized, it is ineffective to exercise any control functions. The advantage of this modification is that DC power is still available until thermostatic switch 32 opens for the operation of auxiliary dryer components, such as a lint indicator or shut-off alarm.

It can thus be seen that this invention provides a moisture responsive dryer control circuit that employs a novel pulse sampling technique to ensure proper and reliable operation. This is accomplished at no increase in circuit complexity since the pulse generating element, capacitor 56, is already in the circuit to provide a pull-in current surge for operating the reed switch coil, and the sampling pulses are thus obtained free.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a clothes dryer having means defining a drying chamber for receiving wet fabrics to be dried, electrode means in said drying chamber for sensing the resistance of said fabrics, an AC power source, heating means connected to said AC power source for supplying heat to said drying chamber, and a control circuit connected to said heating means and to said electrode means for terminating the operation of said heating means in response to a resistance of said fabrics across said electrode means indicative of a dried condition thereof, said control circuit comprising: a storage capacitor connected in parallel with said electrode means; impedance means in series with said storage capacitor; selectively conductive threshold sensing means having a firing potential and an inherent current leakage region within the nonconductive state thereof, said threshold sensing means being conductive when the combined voltage across said storage capacitor and said impedance means reaches said firing potential; means responsive to the conduction of said threshold sensing means for terminating operation of said heating means; DC power supply means connected to said AC power source for supplying a charging current to said storage capacitor, a charge on said storage capacitor increasing toward the firing potential of said threshold sensing means as the resistance of said fabrics across said electrode means increases, and means connected to said power supply means for applying a cyclic pulse signal across said impedance means whereby said cyclic pulse signal drives the threshold sensing means into and out of said current leakage region to minimize current leakage through said threshold sensing means during the nonconductive state thereof.

2. The apparatus of claim 1 wherein said DC power supply means provides a DC signal having a cyclic ripple, and wherein the means for applying a cyclic pulse signal across said impedance means includes a differentiating capacitor connected to said impedance means for converting said cyclic ripple into a cyclic pulse signal.

3. The apparatus of claim 1 wherein the threshold sensing means is a neon lamp.

4. The apparatus of claim 1 wherein said impedance means is a reed switch coil, wherein the charging current supplied by said DC power supply is also supplied to said reed switch coil in a first direction to act as a holding current, wherein said threshold sensing means is connected across the series combination of said storage capacitor and said reed switch coil, and wherein said control circuit further includes a reed switch operatively associated with said reed switch coil for supplying electrical power to said power supply means from said AC power source when closed, whereby the conduction of said threshold sensing means discharges said storage capacitor through said reed switch coil in a second direction opposite to said first direction to thereby reduce the current flow through said reed switch coil to open said reed switch and terminate the operation of said heating means.

5. The apparatus of claim 4 wherein said DC power supply means includes voltage rectifying, filtering and regulating means for converting an alternating signal from said AC power source to a DC signal having a cyclic ripple, said DC power supply means connected in series with said reed switch.

6. The apparatus of claim 1 wherein said impedance means is a reed switch coil, wherein the charging current supplied by said power supply means is also supplied to said reed switch coil in a first direction to act as a holding current, wherein said threshold sensing means is connected across the series combination of said storage capacitor and said reed switch coil, wherein the means responsive to the conduction of said threshold sensing means for terminating the operation of said heating means includes a relay coil, and wherein said control circuit further includes a reed switch operatively associated with said reed switch coil for controlling the energization of said relay coil from said AC power source, whereby the conduction of said threshold sensing means discharges the

storage capacitor through said reed switch coil in a second direction opposite to said first direction, thereby reducing the current flow through said reed switch coil to open said reed switch and terminate the operation of said heating means.

7. The apparatus of claim 6 wherein said reed switch is connected in series with said relay coil, and wherein said power supply means is connected in parallel with said series combination of said reed switch and said relay coil whereby said power supply means continues to operate from said AC power source subsequent to the opening of said reed switch.

8. In a clothes dryer having means defining a drying chamber for receiving wet fabrics to be dried, electrode means in said drying chamber for sensing the resistance of said fabrics, an AC power source, heating means connected to said AC power source for supplying heat to said drying chamber and a control circuit connected to said heating means and to said electrode means for terminating the operation of said heating means in response to a resistance of said fabrics across said electrode means indicative of a dried condition thereof, said control circuit comprising: a storage capacitor connected in parallel with said electrode means; a reed switch coil in series with said storage capacitor; selectively conductive threshold sensing means having a firing potential, said threshold sensing means being conductive when the voltage across said storage capacitor reaches said firing potential; a relay coil responsive to the conduction of said threshold sensing means for terminating the operation of said heating means; DC power supply means connected to said AC power source for supplying a charging current to said storage capacitor, the charge on said storage capacitor increasing toward the firing potential of said threshold sensing means as resistance of said fabrics across said electrode means increases, said power supply means further supplying a holding current in a first direction through said reed switch coil; and a reed switch operatively associated with said reed switch coil and connected in series with said relay coil for controlling the energization of said relay coil, whereby the conduction of said threshold sensing means discharges the storage capacitor through said reed switch coil in a second direction opposite to said first direction to thereby reduce the current flow through said reed switch coil to open said reed switch and terminate operation of said heating means, said power supply means being connected in parallel with said series combination of said reed switch and said relay coil whereby said power supply means continues to operate from said AC power source subsequent to the opening of said reed switch.

9. In a clothes dryer having means defining a drying chamber for receiving wet fabrics to be dried, electrode means in said drying chamber for sensing the resistance of said fabrics, an AC power source, heating means connected to said AC power source for supplying heat to said drying chamber, and a control circuit connected to said heating means and to said electrode means for terminating the operation of said heating means in response to a resistance of said fabrics across said electrode means indicative of a dried condition thereof, said control circuit comprising: a storage capacitor connected in parallel with said electrode means; a reed switch coil in series with said storage capacitor; selectively conductive threshold sensing means having a firing potential, said threshold sensing means being conductive when the voltage across said storage capacitor reaches said firing potential; a relay coil responsive to the conduction of said threshold sensing means for terminating the operation of said heating means; a reed switch operatively associated with said reed switch coil for controlling the energization of said relay coil from said AC power source; a start switch for initiating operation of said clothes dryer, said start switch providing an instantaneous line transient upon closing; a differentiating capacitor in series with said reed switch coil which passes said line transient to said reed switch coil in a first direction for closing said reed switch and initiating operation of said heating means; and DC power supply means connected to said AC power source for supplying a holding current through said reed switch coil in said first direction, said power supply means further supplying a charging current to said storage capacitor, the charge on said storage capacitor increasing toward the firing potential of said threshold sensing means as the resistance of said fabrics across said electrode means increases, whereby the conduction of said threshold sensing means discharges the storage capacitor through said reed switch coil in a second direction opposite to said first direction to thereby reduce the current flow through said reed switch coil to open said reed switch and terminate operation of said heating means.

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