

Nov. 16, 1965

N. L. FUQUA ETAL

3,217,422

LAUNDRY DRYER CONTROL

Filed Dec. 17, 1959

2 Sheets-Sheet 1

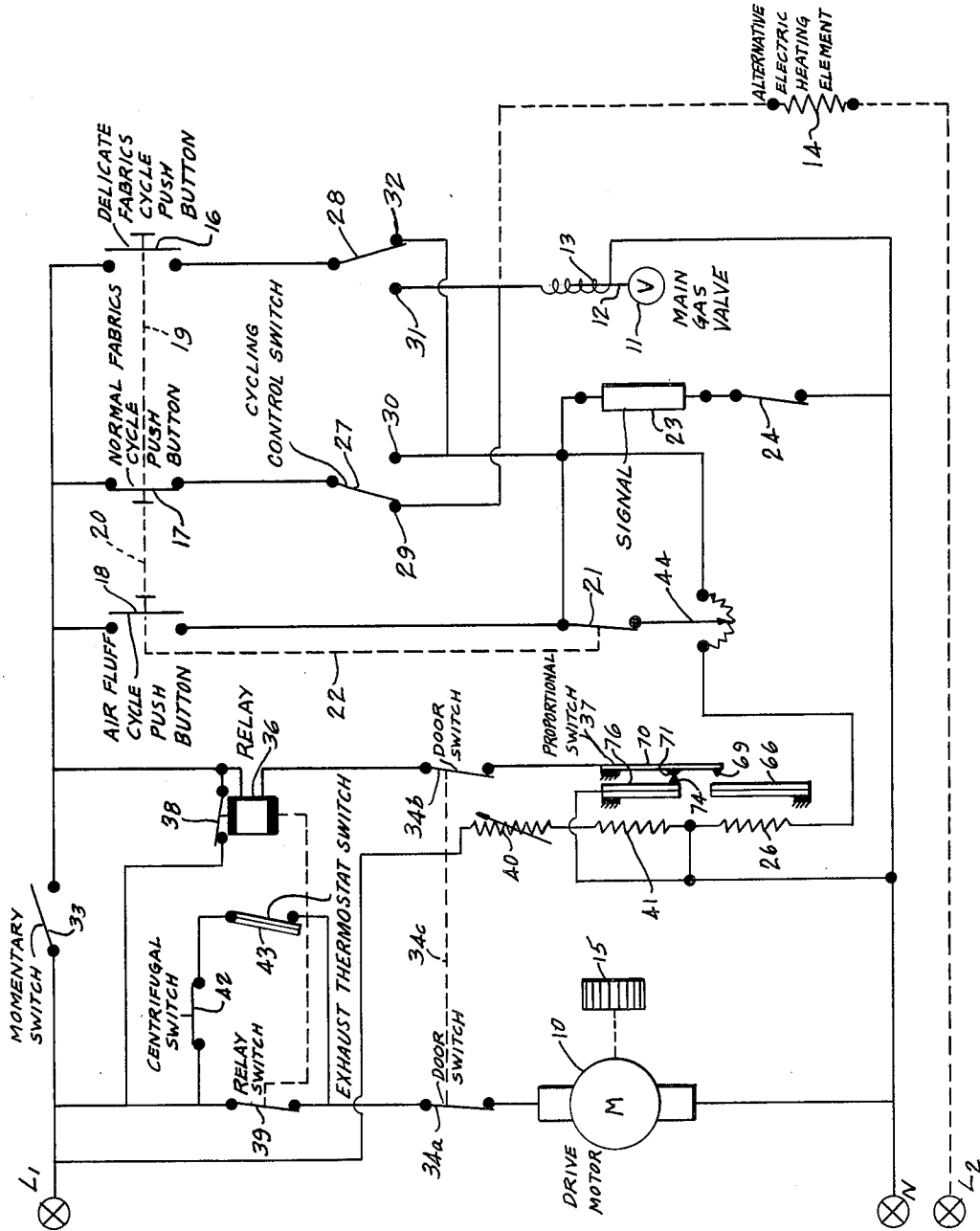


Fig. 1

Inventors

Norman L. Fuqua

James L. Powers

Attys.

Nov. 16, 1965

N. L. FUQUA ETAL
LAUNDRY DRYER CONTROL

3,217,422

Filed Dec. 17, 1959

2 Sheets-Sheet 2

Fig-2

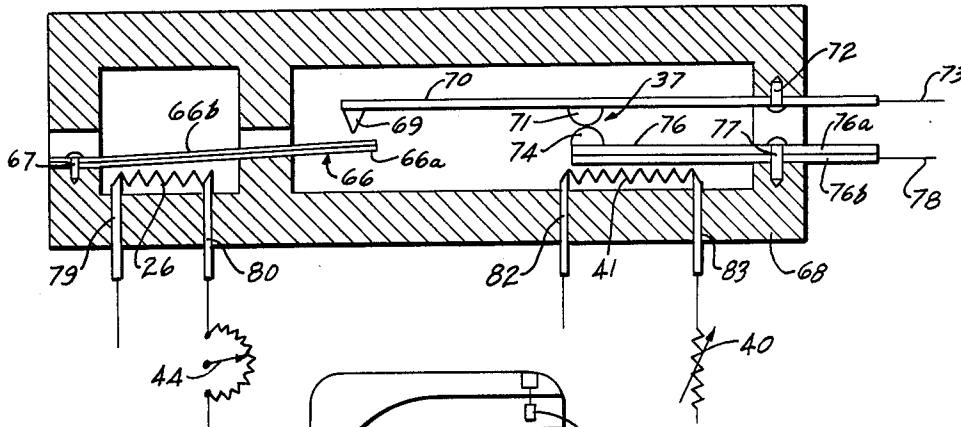


Fig-4

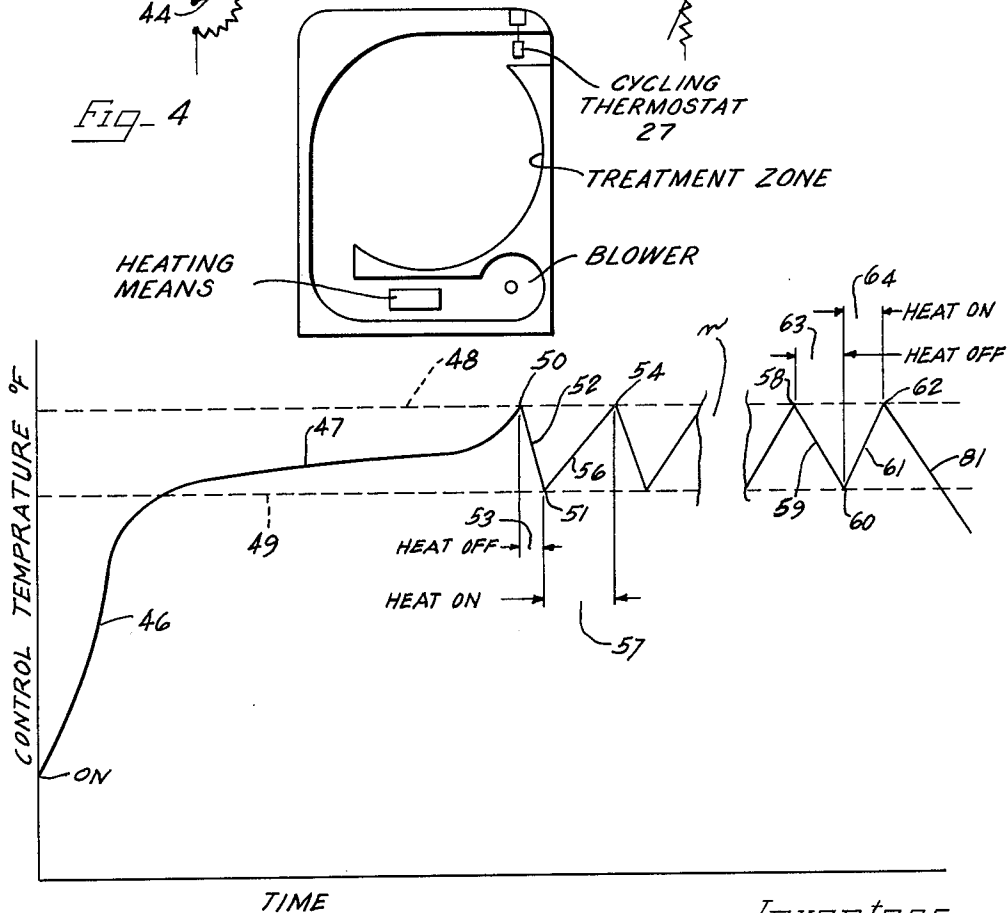


Fig-3

Inventors
Norman L. Fuqua
James L. Powers

BY

Will, Sherman, Meroni, Gross & Simpson Attys.

1

3,217,422

LAUNDRY DRYER CONTROL

Norman L. Fuqua and James L. Powers, Marion, Ohio,
assignors to Whirlpool Corporation, St. Joseph, Mich.,
a corporation of Delaware

Filed Dec. 17, 1959, Ser. No. 860,279

7 Claims. (Cl. 34-45)

This invention relates generally to a laundry appliance and more specifically to a proportional dry control system wherein a current of ventilating air directed through a drying zone is cycled between upper and lower limits of a preselected range of temperature during discrete, successively varying time increments of heating and cooling and wherein the operation of the dryer is controlled as a function of the changing proportion relationship of the discrete time increments with increasing dryness of the materials in the treatment zone.

It is an object of the present invention to provide an improved laundry appliance.

Another object of the present invention is to provide a dryer control system based on a physical condition directly dependent on load-moisture content.

Yet another object of the present invention is to provide a drying control system which eliminates the necessity of using abnormally high control thermostats which are usually used in conventional commercially available dryers incorporating automatic drying control systems.

Yet another object of the present invention is to provide a dryer system which eliminates the necessity of having to rely completely upon clock timers in order to terminate the application of heat energy to articles dried by use of this system.

A further object of the present invention is to provide a dryer control system which is readily adaptable to compensate for significant drying variables.

A still further object of the present invention is to provide apparatus which minimizes any tendency towards overdrying of the materials under treatment.

Still another object of the present invention is to provide a domestic dryer having a control system which is readily compensated for voltage and gas quality variations, as well as for ambient operating conditions, and for air flow variations and which will automatically terminate operation of the device in relation to the dryness of the clothes.

Another object of the present invention is to provide a domestic laundry appliance which is automatic and which may be effectively utilized for either an air cycle or for a normal or delicate fabrics cycle.

Another object of this invention is to provide a domestic type dryer incorporating a control system which provides for a cool down period without the necessity of using a clock timer for operating the dryer during that period.

Many other features, advantages and additional objects of the present invention will become manifest to those versed in the art upon making reference to the detailed description which follows and the accompanying drawings in which a preferred embodiment of the devices incorporating the principles of the present invention and by means of which the methods of the present invention may be practiced are shown by way of illustrative example.

On the drawings:

FIGURE 1 is a circuit diagram illustrating a control circuit provided in accordance with the principles of the present invention;

FIGURE 2 is a somewhat schematic cross-sectional view of a proportional switch incorporated in the control system of FIGURE 1;

FIGURE 3 is a drying curve plotting time against control temperature and illustrating the operation of a

2

control system and method provided in accordance with the principles of the present invention; and

FIGURE 4 is a diagrammatic sketch illustrating in operative relationship a drying chamber with heating means and a cycling thermostat responsive to exhaust temperature.

As shown on the drawings:

Although the principles of the present invention are of general applicability, a particularly useful application of the disclosures herein made, involve the drying of clothes in a domestic clothes dryer. It will be understood, however, that the inventive subject matter may be applied with equal facility to other forms of drying apparatus.

Drying is the removal of an evaporable liquid, usually water, which may be accomplished by heating the wet material to a temperature above that corresponding to the vapor pressure of the surrounding atmosphere, or by reducing the vapor pressure of the surrounding atmosphere below the vapor pressure of the liquid in the material to be dried.

Changing a substance to a vapor state is a process called vaporization, a term which includes boiling and sublimation, as well as evaporation, which is a conversion of liquid to the vapor state that occurs only at the surface of the liquid.

Evaporation occurs at all temperatures and continues until the liquid disappears, or until the space surrounding the liquid has become saturated with vapor. In the process of evaporation, a liquid is gradually transformed to a vapor by loss of molecules at its surface. The molecules of a liquid are regarded as in a state of continual, but disordered motion, moving about in all directions and with various speeds. In this motion there will be instances where a molecule is approaching the liquid surface with a sufficient velocity to carry it beyond the range of attraction of the surface molecule; this molecule then leaves the liquid and becomes a molecule of vapor.

The rate of evaporation of free moisture to be removed from a batch of materials such as clothes, depends upon the vapor pressure of the moisture in the material corresponding to its temperature and the vapor pressure of the moisture in the air corresponding to its absolute humidity, although it will be appreciated that other factors such as the physical properties of the materials being dried and the movement or flow of the ambient air are also involved. In any event, the rate of evaporation is proportional to the difference in vapor pressure between the liquid in the materials to be dried and that of the liquid in the immediate vicinity of the materials to be dried.

The quantity of heat which must be given to a unit mass of liquid to convert it to vapor without a change of temperature, is called the heat of vaporization.

Thus, in a clothes drying operation, the addition of a predetermined quantum of thermal energy per unit of time to an air stream directed into a drying zone, will either result in the conversion of the free moisture into vapor, and will thus be a measure of the heat of vaporization given to the free moisture on the materials within the drying zone, or the temperature of the drying zone and the materials contained therein will be elevated by direct conduction and convection. Thus, if the addition of thermal energy is terminated, the air stream will cool down at a rate reflecting the evaporative conditions in the drying zone.

Accordingly, if the addition of thermal energy to the air stream at a uniform rate is cycled as a function of a sensible temperature differential in the drying zone, the time units of (1) heating time on, and (2) heating time off, for one cycle occurring when most of the added thermal energy is given to the free moisture as heat of evaporation, will be appreciably different than when the added

thermal energy acts largely only to elevate the temperature of the drying zone.

In its simplest form, without compensating for any of the numerous drying variables, the proportional dry control system of the present invention utilizes a heat-sensitive element such as a bimetal, which is influenced by a heating means such as a small low wattage heater arranged adjacent to the bimetal to impose a thermal signal thereon. The circuitry is such that the heater is only energized when a control thermostat cycles the heat input for the dryer off. It will become de-energized when the control thermostat cycles the heat input back on. Thus, during each subsequent cycle, the heater will be on longer and will have less time to cool off. Thus, the ratio of the time increment determined by the proportion of time when the heat input is off, to the proportion of the time when the heat input is on, becomes large enough that the heater will eventually cause the bimetal element to deflect sufficiently to mechanically open the so-called proportional switch which, in turn, controls a relay operating to regulate an electric circuit for the machine.

In other forms of prior art dryer control systems, the operator either selects a certain amount of time on a machine timer, whereupon the machine will run for the time selected, regardless of whether or not the drying heat input is on or off or regardless of whether the load is dry, or in another form of machine, once the dryer is set in operation by the operator, the actuation or energization of the timer will be delayed until the exhaust air temperature increases to a control thermostat cycling temperature whereupon the further operation of the machine will be based upon a time factor which actually has no fixed relation to the moisture content of the clothes load being dried.

Thus, the proportional dry control system of the present invention is based on a physical condition directly dependent on the load moisture content. Many of the components of a dryer incorporating the principles of the present invention may take the form of structure well known in the art and, accordingly, only so much of the structure and operation as is necessary to a proper understanding of the principles of the present invention will be explained in detail. For example, it is contemplated that there will be provided in accordance with the principles of the present invention, a dryer incorporating a drive motor 10 which is used to rotatably drive a fan or blower 15 for pressurizing a stream of air, thereby to direct a current of ventilating air through a treatment zone formed within the dryer structure (not shown). The treatment zone may conveniently take the form of a rotating drum so that a batch of clothes may be tumbled within the drum, while being exposed to the current of ventilating air.

In accordance with the principles of the present invention, the current of ventilating air may have heat of vaporization added thereto either by a gas burner or by an electric heating element. In the circuit diagram of FIGURE 1, a main gas valve is shown at 11 having a movable valve element 12 cooperating with an electric actuator 13. It will be understood that the valve 11 is representative of the usual type of gas control valves incorporated in domestic laundry appliances.

Should the dryer be of the type utilizing an electric heating element instead of a gas heating means, the control circuit of FIGURE 1 would be characterized by the provision of an electric heating element shown at 14, and that portion of the control circuit connected to the heating element 14 would merely be substituted for that portion of the circuit provided for energizing the controls of the gas valve 11.

In either event, the dryer powered by the drive motor 10 would be energized from the usual domestic source including the power lines L_1 and L_2 , a three wire system being shown as including the neutral or ground line at N.

The features of the present invention are illustrated in

connection with a control device contemplating multiple cycles which may be selected by an operator. For example, many of the fabrics contemporarily available comprise acetate fibers or so-called synthetics, which are categorized as delicate fabrics and which should be dried at reduced temperatures. To effect such operation, there is shown a DELICATE FABRICS cycle push button switch 16.

For operation of the dryer with normal fabrics, dried at normal temperatures, there is provided a NORMAL FABRICS cycle push button 17. It is further contemplated that the dryer might be operated without the addition of any heat or thermal energy into the machine, but merely through the circulation of a current of ventilating air. Accordingly, there is provided an AIR FLUFF cycle push button 18.

To initiate a normal or regular drying cycle, the NORMAL FABRICS cycle push button 17 is actuated. It is contemplated that there will be provided a mechanical linkage 19 and 20 between the NORMAL FABRICS cycle push button 17 and the DELICATE FABRICS cycle push button 16 and the AIR FLUFF cycle push button 18 so that actuation of the NORMAL FABRICS cycle push button 17 to a closed circuit position, as shown in FIGURE 1, will automatically open the switch controlled by the DELICATE FABRICS cycle push button 16 and the switch controlled by the AIR FLUFF cycle push button 18. There is also provided a switch 21 mechanically interlinked as at 22 to the AIR FLUFF cycle push button so that whenever one is open, the other is closed. Also, whenever the normal or delicate fabrics cycles are selected, the further control of the machine will include circuitry having an electrically energized signaling device capable of producing either an audible or a visual signal as shown at 23 and also a so-called damp-dry switch 24 adapted to be located on the control console of the machine so the operator may select the use of the feature if desired. Thus, a damp-dry signal will be indicated by the signaling device 23 and since the circuitry for the signal is in exact electrical parallel to circuitry including a proportional heater 26, the signal device 23 will be energized whenever the proportional heater 26 is energized providing the damp-dry switch 24 has been closed on the console.

The control circuit is shown as including a pair of thermostatic switches 27 and 28, the switch 27 being in circuit with the normal cycle push button switch 17 and the switch 28 being in circuit with the DELICATE FABRICS cycle push button switch 16.

The switch 27 moves between two contacts 29 and 30, while the switch 28 moves between two contacts 31 and 32. The thermal sensing elements of the switches 27 and 28 are subjected to dryer exhaust temperature, in other words, the temperature of the current of ventilating air exhausted from the drying zone and operate to cycle the heating means between upper and lower limits of a pre-selected range of temperature during discrete successively changing time increments of heating and cooling.

Having actuated the NORMAL FABRICS cycle push button 17, the operator also momentarily closes a momentary switch 33 in the main power line L_1 , thereby completing a circuit through a safety switch associated with the door closing the access opening of the dryer and hereinafter identified as two separate door switches 34a and 34b, interconnected as at 34c, through a relay 36, and a normally closed proportional switch 37. The energization of the relay 36 closes a relay switch 38, thereby by-passing the momentary switch 33 and also closes a relay switch 39 which completes a circuit through the door switch 34a to the drive motor 10.

Upon operation of the drive motor 10, a centrifugal switch 42 will close, but an exhaust thermostat switch 43 in series with the centrifugal switch 42 will not close until a predetermined exhaust air temperature, for example, a temperature of 120° F. is reached.

The heating means which may be represented by the main gas valve 11, or by the electrical heating element 14, will be energized through the normal cycle control thermostat switch 27 engaged against the contact 29, and the entire circuit will remain in the condition thus far described until the exhaust air temperature increases to a pre-selected upper temperature limit, for example, 165°, whereupon the thermostat control switch 27 will open the circuit to the heating means at 29 and will close the circuit as at 30 to the proportional heater 26 and to a rheostat 44. Also at this time if damp-dry switch 24 has been preset into a closed position, damp-dry signal 23 would be energized for the first time thereby indicating that the fabrics may be removed for ironing.

Correlating the description to the graph of FIGURE 3, the on position effected by actuation of the normal cycle push button 17 by the operator, is indicated by the legend "ON." The warming up period of the dryer is indicated by that portion of the curve identified at 46. When the machine has warmed up to its plateau temperature it is operating on that portion of the curve identified at 47. The top or upper limit of the thermostatic switch 27 is indicated by the dashed line 48 and the lower limit of the thermostatic switch 27 is indicated by the dashed line 49. Thus, if the normal cycle push button has been actuated and the machine has been preset for a normal upper limit at 165°, the thermostatic switch 27 will move from the contact 29 to the contact 30 at the point 50 on the curve.

It is assumed that the dryer has been charged with a load of wet clothes, for example, a load of clothes which has just completed a laundering operation. If the apparatus is a combination washer and dryer, it will be understood that the batch of wet clothes remains in the same container and the machine functions as a dryer following initiation of the drying control cycle.

Since there is probably an average amount of moisture present in the load at the time the dryer has warmed up through that portion of the curve indicated at 46 and reached its plateau temperature, as indicated by that plateau portion of the curve indicated at 47 and reached point 50, the exhaust air temperature will cool rather quickly upon actuation of the thermostatic switch 27 until the control thermostat reset temperature is reached at the point 51. In the exemplary arrangement herein shown, it is assumed that the reset temperature is approximately 155° F., and on the dashed line 49 of the graph of FIGURE 3.

The cooling off period indicated by that portion of the curve marked 52 and extending between the points 50 and 51, covers a discrete time increment marked 53 since the current of ventilating air will continue to flow through the treatment zone. The switch 27 then again moves to the contact 29 whereupon thermal energy or heat is again added to the current of ventilating air and the temperature rises to the point 54, the temperature curve traversing that portion indicated at 56 and covering a time increment 57. Accordingly, the increments 53 and 57 added together cover one complete cycle between the points 50 and 54 on the curve, the increments 53 and 57 comprising a cooling off period and a heating up period, respectively.

With increasing dryness of the clothes load, however, the quantum of thermal energy added to the current of ventilating air during each respective cycle, will either increase the conversion of the free moisture of the heat of vaporization given to the free moisture, or such thermal energy will merely raise the temperature of the drying zone and the materials contained therein. In this regard, it must be borne in mind that heat of vaporization is the quantity of heat given to a unit mass of liquid to convert it to vapor without a change of temperature. Accordingly, with increasing dryness of the clothes, the increments 53 and 57 will change in proportion to one another. Such change is depicted after completion of a

given number of cycles herein referred to as "n" cycles (FIGURE 3), whereupon the beginning of cycle "n+1" is shown at point 58 comprising the cool-down increment 59 to the point 60 and the heating up increment 61 ending at the point 62. In such cycle the first increment is indicated at 63 and the second increment is indicated at 64.

It will be noted from a comparison inspection of the cycles 50-54 and 58-62, that the proportion 53/57 is considerably different from the proportion 63/64. Thus, it is apparent that the addition of thermal energy to the air at a uniform rate having been cycled as a function of a sensible temperature differential in the drying zone, has resulted in the time units of (1) heating time on, and (2) heating time off for one cycle to differ in such a manner as to indicate the desired dryness of the clothes. In other words, initially in the cycle 50-54, most of the added thermal energy was given to the free moisture as heat of vaporization, whereas in the cycle 58-62, it appears the added thermal energy largely acts to elevate the temperature of the zone and the materials contained therein.

In accordance with the principles of the present invention, the proportional control concept is exploited by a proportional control device illustrated in FIGURES 1 and 2.

As previously referred to, there is provided a proportional switch 37 however one of its contact members 71 is conveniently regulated by a thermally responsive or thermosensitive device 66. The thermally responsive device may conveniently take the form of a bimetal including a lamination 66a and a lamination 66b secured by a fastener 67 in a switch housing 68. The end of the bimetal 66 is arranged to operatively engage an actuator end 69 on a stem 70 carrying a switch contact member 71 and being securely assembled by a fastener 72 in the housing 68. The stem 70 is electrically conductive and is suitably connected to a conductor wire 73 for electrical connection to the circuitry of the control system.

A second switch contact member 74 is carried on the end of a bimetal 76 having a lamination 76a and a lamination 76b and being secured in the housing 68 by a fastener 77. The bimetal 76 is electrically connected to a conductor wire 78 for connection to the circuitry of the control device.

By virtue of the inherent resilience of the stem 70, there is a general downward bias of the contact member 71 against the contact member 74, thereby making the proportional switch 37 a normally closed switch.

In the arrangement of FIGURE 2, the proportional heater previously referred to and identified by the reference numeral 26, is shown positioned adjacent the bimetal 66. Conductor connections 79 and 80 for the proportional heater 26 are shown mounted in the housing 68, thereby to facilitate connection of the proportional heater 26 to the circuitry of the control system. In this specific embodiment, the proportional heater 26 takes the form of an electrical resistance which generates heat upon electric current passing therethrough, although it is conceivable that other forms of heating means could be employed.

It will be noted that the proportional heater 26 is in series with the contact member 30 and the contact member 32 of the thermostatic control switches 27 and 28, respectively. Thus, the only time the heater 26 is energized during either the NORMAL FABRICS cycle or the DELICATE FABRICS cycle, is when one of the switches 27 or 28 is positioned in a position corresponding to a heat input portion of the cycle.

Referring now to the initial cycle 50-54 of the graph of FIGURE 3 once again, under ordinary circumstances the heat input off period represented by the increment 53 would not have been long enough for the proportional heater 26 to open the proportional switch via the bimetal 66. Thus, when the 155° exhaust air temperature is reached, the proportional heater 26 is deenergized and heat is again applied by actuation of the heating device

and during the heating period, the bimetal 66 has an opportunity to cool down.

Accordingly, the heat input cycling off and on will continue until the ratio of the "heat off time" to the "heat on time" becomes large enough that the bimetal 66 will be displaced sufficiently to open the proportional switch 37 by separating the contacts 71 and 74.

When the contacts 71 and 74 are finally opened, and the circuitry controlled thereby is broken, the relay 36 is immediately deenergized whereupon both sets of relay contacts represented by the relay switch 39 and the relay switch 38 will be opened. Opening of these two relay switches will deenergize the control circuitry with the exception of a compensation circuit yet to be described, and the drive motor 10 which is still energized through the centrifugal switch 42 and the exhaust air thermostat switch 43 in series therewith. The machine then continues on a cool-down period which is indicated in the graph of FIGURE 3 by that portion of the curve identified at 81, and such cool-down period will continue until the exhaust air temperature decreases to a pre-selected value, for example, 110°, at which time the exhaust air temperature thermostat switch 43 will open and deenergize the entire circuitry to terminate the complete drying operation.

In connection with the theory of operation of this dryer control, it will be appreciated that the predetermined ratio of "heat input off" time to the "heat input on" time is used as an index of measurement of the response of thermal sensitive bimetal element 66 to the heat energy which it receives and accumulates from its heater 26 in addition to that heat energy received and stored from the ambient atmosphere. Bimetal element 66 therefore in effect becomes a heat sump or reservoir for heat energy absorbed from both heater 26 and the ambient atmosphere. However, due to normal usage of the dryer in a relatively constant range of ambient temperature for a particular load being dried, it is primarily those variations in the absolute heat energy level of bimetal 66 due to heater 26 that produce the necessary deflection of bimetal 66 which results in the separation of contacts 71 and 74 of switch 37. As will be explained hereinafter, extreme variations in the ambient temperature from load to load for a given dryer are compensated by a circuit mechanism capable of selecting the proper proportional ratio commensurate with the variations in the ambient. Of course, as this ambient compensating circuit mechanism selects a new proportional ratio, it also changes the absolute heat energy level of bimetal 66 necessary for bimetal 66 to open proportional switch contacts 71 and 74.

Assuming relatively constant ambient temperature conditions while drying a particular load, the deflection of bimetal 66 is therefore directly dependent upon the heat energy it has accumulated and stored at a given moment, variations in that heat energy level being dependent upon heater 26 and the frequency and duration of its energization. For example, when the air heating element 14 has first been cycled off by movement of thermostatic switch 27 and the bimetal heater 26 is energized, bimetal 66 moves to a position commensurate with its increased absolute heat energy level with that position theoretically differing from its initial position. When the bimetal heater 26 is deenergized and the air heater 14 is again energized, the absolute heat energy level of bimetal 66 will drop due to heat loss but probably will not decrease to its initial level before thermostatic switch 27 is again cycled. Subsequent deenergization of air heater 14 and energization of heater 26 by switch 27 will ultimately increase this absolute heat energy level, during that or subsequent cycles, to a level high enough to cause deflection of bimetal 66 to separate contacts 71 and 74 and permanently shut off the air heater 14.

Since variations in the absolute heat energy level of the thermally responsive bimetal element 66 have been

found to be correlated to the ratio of the successively increasing "heat input off" intervals to the successively decreasing "heat input on" intervals, it will be appreciated that these changing ratios, which are inherent in each cycle of operation as shown in FIGURE 3, represent an index of the variations in the heat energy level of bimetal 66. The point of final deenergization of the air heater 14 may then be said to correspond to a predetermined ratio of "heat input off" time or to the absolute heat energy level of bimetal 66.

The basic proportional control system thus far described is eminently practical since it is based on a sound criterion of moisture retention. Additionally, there are many other advantages in its use since it readily lends itself to being used with other electric circuit elements to compensate for the important drying variable which are introduced by the necessity of operating dryers in different climates and in different geographical locations subject to variations in power supply.

Perhaps the three most important variable that highly complicate the provision of an effective dryer control system are (1) variable gas quality or voltage supply in the power system, (2) variations in ambient temperature conditions, and (3) variable air flow. Each of these three variable operates completely independent of the other.

For example, in some areas of the United States, it is common for installation voltages to be considerably less than the optimum voltage contemplated by the machine designed. Since wattage usage of the air heater input varies with the voltage squared with constant resistance heating elements, a low supply voltage results in an air heater input wattage much lower than the rated value. This not only extends the drying time, but more important from the drying control standpoint, it results in the heat input first being cycled off at a lower moisture retention. Under such circumstances, the tendency of the machine towards overdrying would produce very harmful effects on the clothes being dried. It will be understood that an above average supply voltage would result in an opposite effect, thereby deteriorating the sophistication of control likely to be obtained. In machines utilizing a gaseous fuel heater, the same effects are likely to occur due to variations in the quality of the fuel, or to selection of an improper burner orifice.

Variations in ambient temperatures are particularly likely to occur where the drier has been installed either in a basement, or on a porch or a breezeway or in a garage. As the installation ambient decreases, the plot of exhaust air temperature versus drying time moves downward, but remains almost exactly parallel to the plot before decrease of the ambient. Although the actual drying rate is not appreciably affected by ambient changes, with a decreased ambient it will take considerably longer for the exhaust air temperature to reach the control thermostat "heat input off" temperature level. Thus, the first cycle point will occur at a much lower moisture retention or even in a complete dry condition. Accordingly, the risks of over-drying are increased with low ambient conditions. An increase in ambient temperature above average conditions will result in an opposite effect.

Although dryer apparatus may be of uniform construction, it will be appreciated that air flow vent lengths vary depending upon the individual installation. Accordingly, as air flow vent length is increased, air flow is reduced because of the pressure drops occurring along the length of the vent. This results in more heat input per unit volume of air flow which results in a higher exhaust air temperature versus drying time plot. Because of the increased exhaust air temperature, the control thermostat will cycle the heat input off earlier and will result in a higher load moisture retention at the time of cycling.

With respect to the variables discussed hereinabove, it may be noted that for the life of a particular dryer installa-

tion, the supply voltage is likely to remain practically constant and the air flow is also likely to remain constant since the venting will vary only slightly downward with machine lint build-up. Ambient temperatures, however, will vary a great deal since atmospheric conditions are frequently involved.

In accordance with the principles of the present invention, the dryer control system is adequately compensated for the three important variables discussed hereinabove. First of all, in order to compensate for variations in voltage and air flow, a manual compensation adjustment can be effected by the installer. It is contemplated in accordance with the principles of the present invention to place a manually adjustable rheostat 44 in series with the proportional heater 26. In a typical installation, the rheostat 44 can be manually adjusted to vary the voltage across the proportional heater from supply voltage to approximately 64% of the supply voltage. With a 120-volt voltage supply typical of a normal domestic supply, it will be appreciated the proportional heater 26 wattage may be varied from 16 to 6.61 watts, for example.

Thus, if conditions are such that both a high supply voltage and considerable venting or low air flow lead to the air exhaust temperature reaching the thermostat "heat input off" cycle point with a considerable amount of moisture remaining in the load, the rheostat 44 would be adjusted to reduce the voltage across the proportional heater 26 to a lower value than what it would be for an average voltage and vent condition. By so doing, enough heater input cycling would subsequently be allowed to evaporate the remaining moisture. In other words, by making the adjustment the wattage output of the proportional heater 26 would be reduced to the point that it would take a longer "heat input off" period to open the proportional switch 37. Such adjustment would, therefore, assure a dry load when the machine is automatically shut off.

An optimum adjustment is made when a near maximum voltage is afforded across the proportional heater 26 where low voltage and high air flow exists. When air flow and voltage are at the extremes to cause opposite drying effects, a weighted average adjustment would have to be made on the rheostat 44.

In accordance with the principles of the present invention, ambient compensation is effected automatically. The ambient compensator includes the thermistor or ambient-sensitive resistance 40. The thermistor or ambient-sensitive resistance 40 has the property of a decreasing resistance with an increasing ambient. The thermistor 40 is in series with a proportional compensator heater 41 mounted to be physically adjacent the bimetal 76 for the purpose of imposing a thermal signal thereon and shown in FIGURE 2 as connected to conductor members 82 and 83 mounted in a switch housing 68. The thermistor 40 is in series with the resistance 41 which, of course, takes the form of an electrical resistance capable of generating heat when electric current is passed there-through.

The thermal energy or heat produced by the proportional compensator heater 41 is sensed by the bimetal 76 so that the bimetal 76 will deflect in an upward direction upon being heated, using the orientation of FIGURE 2.

The thermistor 40 and the proportional compensator heater 41 are connected directly across the voltage source L_1N so they will be energized whenever the machine is plugged in. Thus, the voltage across the proportional compensator heater 41 is controlled by the thermistor 40 and if the ambient temperature increases, the thermistor resistance will decrease, thereby allowing the voltage across the proportional compensator heater 41 to increase. This results in a greater deflection of the adjacent current-carrying bimetal 76, thereby biasing the contact member 74 upwardly against the downwardly biased contact member 71, using the directional orientation of FIGURE 2. Such adjustment would, in turn, require that the bimetal 66 be heated for a longer period of time in order to pro-

duce sufficient mechanical movement for opening the switch contacts 71, 74. Thus, a proper automatic correction for high ambient conditions is automatically effected.

A high ambient will cause the dryer to first cycle at a higher moisture retention than with normal ambient temperatures so the heat input will have to cycle more times and increase the proportional ratio before the load is dry. This is achieved with the automatic compensation described since the proportion of "heat off time" to "heat on time" has been increased.

A low ambient condition, on the other hand, would decrease the proportion of "heat off time" to "heat on time," thus resulting in fewer cycles since the load would be nearly dry or even dry when it is first cycled.

It will be appreciated that since the proportional compensator heater 41 is energized during the entire operation of the dryer, its adjacent bimetal element 76 achieves a certain degree of deflection and remains in such position of adjustment, whereas the proportional heater 26 is only energized when the heat input is cycled off so that its adjacent bimetal element 66 does not reach its full deflection before the proportional heater 26 is deenergized.

To operate the machine and the control system provided therefor, in accordance with the principles of the present invention through a so-called DELICATE FABRICS cycle, the DELICATE FABRICS cycle push button 16 is depressed whereupon the components of the system function exactly as the normal or regular dry cycle except that the control thermostat 28 controls the heat input cycling, instead of the control thermostat 27. As previously noted, the thermostat 28 can be set to cycle at lower temperatures, for example, to open at 135° F. and to close at 125° F. When the DELICATE FABRICS cycle push button 16 is depressed, the NORMAL FABRICS and AIR FLUFF cycle push buttons 17 and 18 are automatically opened.

To operate the machine and the control system therefor in an air fluff cycle, the AIR FLUFF cycle push button 18 is actuated, whereupon the NORMAL FABRICS and DELICATE FABRICS cycle push buttons 16 and 17 are open, together with the rheostat switch 21. Under such circumstances, the heating means will not be energized since in a gas installation, the gas valve 11 will remain closed or in an electric installation the electric heating element 14 will remain deenergized. Since the rheostat switch 21 is open, the proportional heater 26 will have the lowest voltage across it that is possible with the installation supply voltage. Accordingly, the bimetal 66 associated with the proportional heater 26 will deflect upward at its slowest possible rate until sufficient time has passed to allow it to deflect and open the proportional switch by separating the contacts 71 and 74. When the proportional switch 37 opens, the relay 36 is deenergized and both sets of relay contacts controlled by the relay switches 38 and 39 will be opened, thus deenergizing the entire control circuitry, the exhaust thermostat switch 43 already being open since there was no heat available to close the same.

Although various minor modifications might be suggested by those versed in the art, it should be understood that we wish to embody within the scope of the patent warranted hereon, all such modifications as reasonably and properly come within the scope of our contribution to the art.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a dryer, heat-applying means and circuit control means regulating the operation thereof and comprising thermostatic switch means cycling the control of said heat-applying means between upper and lower limits of a selected range of temperature in the dryer, whereby separate discrete time increments of heating and cooling characterize each cycle and the proportional relation-

ship of said time increments varies with increasing dryness of the materials being dried, and additional control means responsive to a selected proportional relationship when the heating increment bears such relationship to the cooling increment as to indicate the materials being dried are substantially dry, said additional control means comprising a switch to terminate operation of the dryer and having a first bi-metal and a stem normally separated but engageable with one another upon movement of said first bi-metal, said stem carrying a first contact of said switch, a proportional heater in heat exchange relation with said first bi-metal to heat said first bi-metal during one of said time increments, said first bi-metal diffusing energy during the other time increment and storing up the difference of thermal energy received but not diffused and being operable to actuate said stem and open said switch upon detecting a predetermined change in the proportional relationship of said time increments, a second bi-metal carrying the other switch contact of said switch, and being disposed to adjustably position said stem relative to said first bi-metal, and a compensator heater in heat exchange relation with said second bi-metal to control the adjustment of said stem automatically.

2. In a dryer as defined in claim 1, a rheostat in control of said proportional heater to effect a compensation adjustment for variations in voltage and air flow.

3. In a dryer as defined in claim 1, an ambient sensitive resistance in control of said compensator heater to effect a compensation adjustment for variations in ambient conditions.

4. A dryer comprising means forming a drying zone, a control circuit comprising first circuit means including electrically regulated heating means whereby a current of heated ventilating air may be directed into and moisture-laden air may be discharged from the drying zone, a normally closed switch in control of said first circuit means, a thermally sensitive actuating element in control of said normally closed switch, local heating means to impose thermal signal on said actuating element, a thermostatic switch in said first circuit means having thermostatic sensing means subject to zone temperature and cycling said thermostatic switch between first and second contacts for cycling said first circuit means between upper and lower limits of a sensible drying zone temperature range, thereby alternately producing a heating period and a cooling period in said zone varying in duration in accordance with the dryness of the materials in the drying zone, circuit means connecting said local heating means with one of said contacts to operate said local heating means alternately in two separate increments corresponding to the heating period and the cooling period in said drying zone, said thermally sensitive element being alternately heated and cooled and actuating said normally closed switch to open position to de-energize the first circuit means only in response to that predetermined deviation of proportion between said two separate increments indicating a desired dryness of the materials in the treatment zone, and a rheostat connected in series with said electrical resistance to compensate for voltage variations and air flow variations.

5. A dryer comprising means forming a drying zone, a control circuit comprising first circuit means including electrically regulated heating means whereby a current of heated ventilating air may be directed into and moisture-laden air may be discharged from the drying zone, a normally closed switch in control of said first circuit means, a thermally sensitive actuating element in control of said normally closed switch, local heating means to impose a thermal signal on said actuating element, a thermostatic switch in said first circuit means having thermostatic sensing means subject to zone temperature and cycling said thermostatic switch between first and second contacts for cycling said first circuit means between upper and lower limits of a sensible drying zone temperature

range, thereby alternately producing a heating period and a cooling period in said zone varying in duration in accordance with the dryness of the materials in the drying zone, circuit means connecting said local heating means with one of said contacts to operate said local heating means alternately in two separate increments corresponding to the heating period and the cooling period in said drying zone, said thermally sensitive element being alternately heated and cooled and actuating said normally closed switch to open position to deenergize the first circuit means only in response to that predetermined deviation of proportion between said two separate increments indicating a desired dryness of the materials in the treatment zone, said circuit means further including adjustable means for varying the wattage output of said local heating means to compensate for energy input level variations to said heating means.

6. A dryer comprising means forming a drying zone, a control circuit comprising first circuit means including electrically regulated heating means whereby a current of heated ventilating air may be directed into and moisture-laden air may be discharged from the drying zone, a normally closed switch in control of said first circuit means, a thermally sensitive actuating element in control of said normally closed switch, local heating means to impose a thermal signal on said actuating element, a thermostatic switch in said first circuit means having thermostatic sensing means subject to zone temperature and cycling said thermostatic switch between first and second contacts for cycling said first circuit means between upper and lower limits of a sensible drying zone temperature range, thereby alternately producing a heating period and a cooling period in said zone varying in duration in accordance with the dryness of the materials in the drying zone, circuit means connecting said local heating means with one of said contacts to operate said local heating means alternately in two separate increments corresponding to the heating period and the cooling period in said drying zone, said thermally sensitive element being alternately heated and cooled and actuating said normally closed switch to open position to de-energize the first circuit means only in response to that predetermined deviation of proportion between said two separate increments indicating a desired dryness of the materials in the treatment zone, said circuit further including a compensating device sensitive to ambient temperature for controlling said thermally responsive device to compensate for varying ambient temperatures.

7. A dryer comprising means forming a drying zone, a control circuit comprising first circuit means including electrically regulated heating means whereby a current of heated ventilating air may be directed into and moisture-laden air may be discharged from the drying zone, a normally closed switch in control of said first circuit means, a thermally sensitive actuating element in control of said normally closed switch, local heating means to impose a thermal signal on said actuating element, a thermostatic switch in said first circuit means having thermostatic sensing means subject to zone temperature and cycling said thermostatic switch between first and second contacts for cycling said first circuit means between upper and lower limits of a sensible drying zone temperature range, thereby alternately producing a heating period and a cooling period in said zone varying in duration in accordance with the dryness of the materials in the drying zone, circuit means connecting said local heating means with one of said contacts to operate said local heating means alternately in two separate increments corresponding to the heating period and the cooling period in said drying zone, said thermally sensitive element being alternately heated and cooled and actuating said normally closed switch to open position to de-energize the first circuit means only in response to that pre-determined deviation of proportion between said two separate increments indicating a desired dryness of the materials in the

13

14

treatment zone, said normally closed switch having a pair of contact members, one of said contact members comprising an adjustably movable bimetal switch element, a proportional compensator heater to impose a thermal signal on said bimetal switch element, and an ambient sensitive resistance in series with said heater and responsive to variations in ambient temperature to control the voltage across the proportional compensator heater.

2,878,579	3/1959	Fuchs	34—45
2,882,610	4/1959	Hughes	34—45
2,895,230	7/1959	Reiley	34—45
2,921,173	1/1960	Kueser	200—122
2,946,212	7/1960	Houser	200—122
3,028,680	4/1962	Conlee	34—45
3,050,865	8/1962	Morey	34—45
3,109,717	11/1963	Clapp	34—45

References Cited by the Examiner

10

FOREIGN PATENTS

UNITED STATES PATENTS

225,397 4/1959 Australia.

2,505,041	4/1950	Gorsuch	34—45
2,621,423	12/1952	Clark	34—45
2,775,047	12/1956	Morrison	34—45
2,815,416	12/1957	Kumler	34—45

15

PERCY L. PATRICK, *Primary Examiner*.
CHARLES O'CONNELL, NORMAN YUDKOFF,
GEORGE D. MITCHELL, *Examiners*.