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AUTOMATIC DRYER CONTROL

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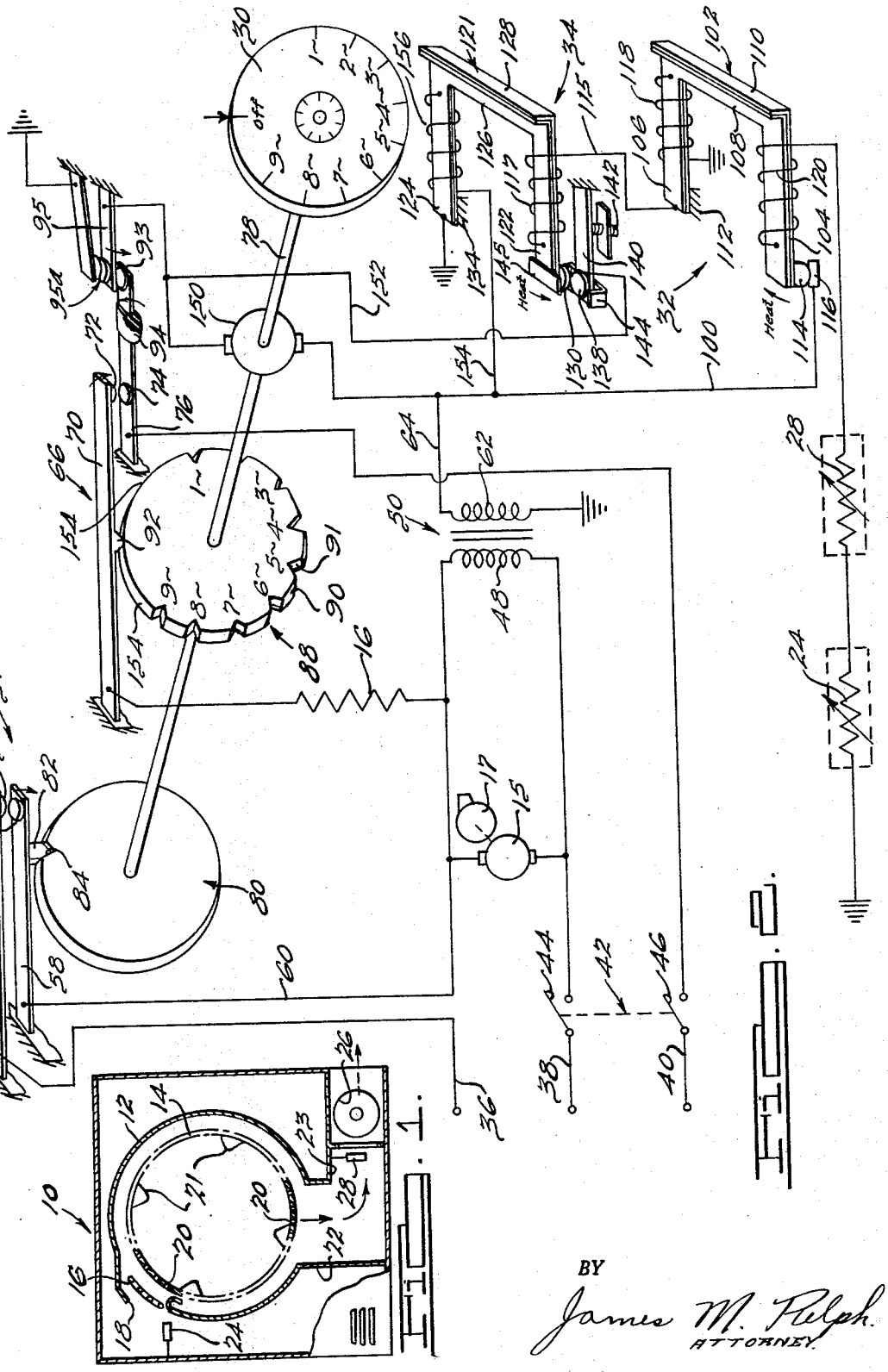


Fig. 1.

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AUTOMATIC DRYER CONTROL

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This invention relates to temperature control systems and more particularly to an improved control system for an automatic dryer of the type where material is tumbled in a rotating drum or basket through which heated air is circulated.

Automatic dryers heretofore have been controlled by the trial and error selection of a predetermined time during which a heating unit such as a gas burner or an electrical heating unit is energized to produce a desired degree of dryness in the dryer load. With such control the time factor in drying lightweight loads is unusually critical since the rate of drying is relatively rapid resulting in overdrying unless great care is taken in selecting the time period in which the drying occurs. Furthermore, heavy loads are often damp following a trial and error selection of the time needed to dry. Consequently, automatic dryer controls often include means to assure overdrying of the load. A common control arrangement continues the drying of the load until the exhaust temperature of the heated air circulating through the load reaches a level which indicates that all moisture has been removed from the dryer load. Such systems, obviously are incapable of automatically controlling dryer operation to produce different degrees of dampness in the dryer load. Such control is desirable since many present day fabrics are wrinkle-free if a predetermined degree of moisture is retained or in some instances are easier to iron in a damp condition.

The present invention is directed to an improved dryer control system which automatically controls the heat input to a dryer in order to attain desired varying degrees of dampness or complete drying of the dryer load. The improved control system reduces drying periods for a given size load and a desired dampness and is, therefore, more economical to operate. The improved system also eliminates the trial and error procedure heretofore encountered in manually adjusted temperature-time controls by replacing such controls with a single selector dial having a wide range of settings to give desired types of drying for varying sized loads including different types of fabrics. Once the dial is set for a desired degree of dryness the desired result will automatically occur, substantially regardless of the size of the load or the materials included in it. An operator can select, for example, substantially independently of the size of the load, the exact dampness desired for ironing or retain a desired dampness in wash and wear fabrics for wrinkle-free drying.

The primary objects of this invention are to improve automatic dryer control by conjointly sensing the inlet and outlet duct conditions to control the drying action; to obtain varying degrees of dampness or complete dryness in loads of variable weight and character by conjointly sensing the inlet and outlet duct temperatures, heating the dryer load until a combined temperature effect occurs in the inlet and outlet ducts, cooling the dryer load for a predetermined period and then reheating the dryer load until the combined temperature effect reoccurs in the ducts to initiate another cooling period, and repeating the control cycle until the desired degree of dampness occurs; to provide such control by including a first senser in the inlet duct of the dryer and a second senser in the outlet duct of the dryer to conjointly control responder means which start and stop a timer-motor for driving cam selector means which open and close switch

means to establish cyclical heating and cooling of the dryer load until the desired degree of dryness is attained; and to provide an improved control system for obtaining such a cyclical action in which means are provided to compensate for ambient temperature and to compensate for varying voltages in the energy source of the improved control system.

With the above as well as other and in certain cases more detailed objects in view, a preferred but illustrative embodiment of the invention is shown in the accompanying drawing, throughout the several views of which corresponding reference characters are used to designate corresponding parts and in which:

FIGURE 1 is a somewhat diagrammatic view in vertical section of one form of a dryer having the dual sensers of the present invention mounted therein; and

FIGURE 2 is a schematic diagram of the control system of the present invention.

Referring now to the drawing, in FIGS. 1 and 2, a domestic dryer assembly **10** of conventional form is shown as comprising a housing **12** in which a drum or basket **14** is rotatably mounted and arranged to be driven by a motor **15**, which also drives a blower **17**, which forces a current of air past a heater **16** mounted in an opening **18** in the housing **12** and through apertures **20** in the drum **14**. Blower **17** may be conventionally mounted in housing **12**, as will be understood. Suitable projections **21** on the inner wall of the drum **14** tumble the dryer load during rotation of the drum **14** to obtain uniform drying therein. The heater **16** of the illustrated embodiment is an electrical heating coil which by way of further example could be a gas burner unit located upstream of the rotatable drum **14**.

The air passes through an inlet duct **22** in which a thermally-responsive senser **24** is located, for example, immediately upstream of the heater **16**. The air is heated by the heater **16** and then passes through a load of clothes or the like carried by the rotatable drum **14** into an exhaust duct **23** and through an inlet **26** to the blower **17**. The temperature of the air in the exhaust duct **23** is sensed by a thermally-responsive senser **28** located, for example, immediately upstream of the inlet to the blower. The spaced sensers **24, 28** conjointly act to control the degree of dryness desired in the dryer load in a manner to be discussed. It is assumed in the illustrated arrangement that the dual sensers **24, 28** are constructed of metallic wire having a high positive temperature coefficient of resistance although, as discussed below, with appropriate changes in the circuitry sensers having high negative temperature coefficients of resistance could be employed. It has been found, in accordance with certain of the concepts of the invention, that the use of such conjointly acting dual sensers has freed the drying action from the variables otherwise caused by load size and the material included in it.

In the illustrated embodiment of the invention, the drying action is controlled by the dual sensers **24, 28** through a control system comprising a pulser **32** directly controlled by the dual sensers **24, 28** and a responder **34** directly controlled by the pulser **32** and which controls the cycling of the system and so controls the supply of heat to the dryer. The construction and mode of operation of pulser **32** and responder **34** are discussed in more detail below.

In accordance with the illustrated embodiment of the present invention, a single selector dial **30** is manually adjustable to select the degree of dryness desired in the dryer load. In use, dial **30** is rotated in a counterclockwise direction from its normal illustrated off position through a range of settings, for example, from 1 to 9 cycles of operation. In one working embodiment, a setting of 8 or 9 cycles provided a substantially complete

drying of all loads; a setting of 5, 6 or 7 cycles left from 5% to 18% of moisture at all loads; a setting of 3 or 4 cycles corresponded to a moisture content of 18% to 35% at all loads; and a setting at 1 or 2 cycles left 35% to 50% of moisture at all loads. It should, of course, be appreciated that these figures are merely representative of one working embodiment of an arrangement embodying the concepts of the present invention.

The source which supplies the electrical energy for the control system and the electric heater **16** may be, for example, a usual source of alternating voltage such as is found in the home and is representatively illustrated as a 3-wire source with a nominal 115-volt alternating potential existing between wires **36** and **38** (the neutral wire) and with a nominal 230-volt alternating potential existing between wires **36** and **40**.

A usual door switch **42** operated by the door (not shown) leading to basket **14**, has pairs of contacts **44** and **46** in wires **38**, **40**, respectively. When the contacts **44**, **46** are closed (the position occupied thereby when the door is closed) current is supplied to the primary winding **48** of a step-down transformer **50**, and to blower motor **15**, from the wire **36**, through a normally open control switch **51**, conductor **60** in parallel through winding **48** and motor **15**, and thence through contacts **44** to the neutral wire **38**. Switch **51** has a spring contact blade **52** carrying a first passive contact **54** which is adapted to be engaged with a movable contact **56** carried by a spring contact blade **58** in spaced parallelism with and biased away from the spring contact blade **52**.

The main electrical heater **16** is connected across the wire **40** and conductor **60** through additional normally open door switch contacts **46** and through a normally open main heater switch **66** having a spring contact blade **70** carrying a contact **72** which is biased toward a contact **74** carried on a spring contact blade **76** which is in turn biased toward the contact blade **70**.

Closing of the dryer door which normally but does not necessarily precede setting of dial **30**, thus normally conditions the system for operation, but does not initiate a drying operation due to the open condition of the main control switch contacts **54**, **45** and the power contacts **72**, **74**.

To initiate a drying action, after closure of the door switch contacts **44**, **46**, the selector dial **30** is turned counterclockwise to a predetermined setting corresponding to the degree of dryness desired. The counterclockwise turning of the selector dial **30** rotates a shaft **78** attached thereto which carries a selector cam **80** having a peripheral edge portion engaging a follower arm **82** on the spring contact blade **52** portion of the control circuit switch **51**. In the illustrated or off position of dial **30**, follower **82** engages in notch **84** of cam **80** and control contacts **54**, **56** are separated; in all other positions of dial **30**, follower **82** rides upon the periphery of cam **80** and contacts **54**, **56** are closed.

The shaft **78** also carries a selector cam **88** having a plurality of peripheral land portions **90** and notches **91** on its periphery. In the illustrated off position, follower **92** on blade **70** of switch **66** rests upon the periphery of cam **88** and power contacts **72**, **74** are separated. Rotation of the cam **88**, for example, to the 5-cycle position, causes cam follower **92** to move into and out of the 1 through 4-cycle notches and to drop into the 5-cycle notch **91**. When the follower arm **92** is in a notch **91** on the periphery of the cam, the spring contact blade **70**, which is biased toward the spring contact blade **76**, moves the contact **72** into engagement with the contact **74** on the blade **76**. The contact carrying end of the spring blade **70** continues to move downwardly after the contacts **72**, **74** are in engagement to move a pusher portion **93** on the end of, but insulated at **94** from, the blade **76** out of supporting engagement with spring contact blade **95**, enabling it to move downwardly under its own bias and separate contacts **95***a*. The contacts **95***a* are closed when the follower arm **92** is in engagement with a land portion **90** on the periphery of the selector cam **88**, and are separated at all other times.

Thus, with the dryer door closed, turning of dial **30** to one of its "set" positions, closes control contacts **54**, **56** and also closes power contacts **72**, **74**. Closure of control contacts **54**, **56** completes the previously traced circuits for the primary winding **48** of control transformer **50** and for the drum and blower motor **15**, thereby putting the drum into rotation and inducing a flow of air through the inlet duct **22**, and through drum **14** and thence through the outlet duct **23**. This current of air, of course, passes over and governs the temperatures of sensers **24** and **28**. Energization of the step-down transformer **50** supplies power through the conductor **64** and a conductor **100** to actuate the pulser and responder portions **32**, **34**, respectively, of the control circuit. Closure of power contacts **72**, **74** energizes the main dryer heater **16**, as aforesaid, and so initiates a rise in temperature of the air stream passing through the basket and over the sensers **24**, **28**.

Except as qualified below, pulser **32** may and preferably does have the structure and mode of operation of pulser-regulator **16** of United States Patent No. 2,835,885 to Leonard Boddy. More particularly, pulser **32** includes a thermally-responsive polymetallic element **102** of generally U-shaped form having a first leg portion **104** and a second leg portion **106** in spaced parallelism lying in a common plane. They are interconnected by a cross arm **108** having an upstanding flange **110** which is provided to increase the stiffness of the cross arm to the point that the cross arm will not deflect to any significant degree in response to the mechanical or thermal forces to which the unit is subjected. It will be appreciated that the U-shaped form of the polymetallic element **102** renders it substantially insensitive to changes in ambient temperature. The outer end of the second leg portion **106** is secured to a fixed support as indicated by the earthing symbol **112** which does not connote electrical grounding. The outer end of the first leg portion **104** carries a movable contact **114** for cooperation with a fixed contact **116** opposite to and spaced therefrom.

The contacts **114**, **116** are initially closed when the control circuit is first energized and are opened by differential heating of the leg portions **104**, **106** which is controlled by a voltage amplifying winding **118** and an operating winding **120** in intimate heat transfer relationship with the leg portions **106**, **104**, respectively, and more particularly being wound thereon. One end of the operating winding **120** connects to the leg portion **104** and contact **114** and its opposite end connects through the inlet and exhaust sensers **24** and **28** to ground. Contact **116** is directly connected to secondary winding **62** of transformer **50** through conductors **100** and **64**. Consequently, energization of transformer **50** by operation of dial **30**, as aforesaid, initiates a flow of current through sensers **24**, **28** and winding **120**. (A similar flow is also initiated through winding **118** but this may be neglected for the time being and is later described.)

When the inlet and exhaust duct temperatures are low the heating output of the operating winding **120** is at a maximum because the sensers **24**, **28** are cool and their resistance is relatively low causing a relatively high current flow through the operating winding **120**. Heat output from the operating winding **120** raises the temperature of the movable contact carrying leg portion **104** relative to the leg portion **106** and ultimately causes the fixed and movable contacts **114**, **116** to separate and interrupt the flow of current through the operating winding **120**. The temperature differential between the movable contact carrying leg portion **104** and the leg portion **106** is then reduced and the contacts **114**, **116** reclose. Then the operating winding **120** again heats the leg portion **104** and opens the contacts **114**, **116**, which thereafter reclose as before.

Thus the pulser **32** functions to maintain the contacts **114, 116** in a condition of incipient opening and closing with the temperature of the contact carrying leg portion **104** undulating about that temperature at which the contacts **114, 116** just open. More particularly, the rate of energy consumption by winding **120** may, of course, be expressed in terms of watts (E^2/R), and since with relatively constant radiating conditions the resistance of operating winding **120** may be assumed to be substantially constant, it follows that for any given value of the resistances of the dual sensers **24** and **28**, the effective voltage appearing across the operating winding **120** is substantially constant and is insensitive to variations in the voltage output of winding **62** of transformer **50**. It also necessarily follows that the effective voltage appearing between the closed contacts **114, 116** and ground remains substantially constant and insensitive to changes in source voltage.

The just-mentioned effective voltages are, however, affected by the resistance values, and hence the temperatures of the sensers **24, 28**. More particularly, as the inlet and outlet temperatures rise, the resistances of the sensers **24** and **28** also increase. The increased senser resistance correspondingly reduces the magnitude of the current pulses flowing through the operating winding **120** during each closed period of contacts **114, 116**. Since the wattage requirement of the operating winding **120** remains constant, this decrease in instantaneous current magnitude must be and is accompanied by an increase in the ratio between the closed and open periods of the contacts **114, 116** of the pulser **32**. Thus, the net effect of the increase in the resistance of the sensers **24, 28** is to correspondingly increase the effective output voltage between the pulser contacts **114, 116** and ground.

In the illustrated arrangement, the responder **34** also comprises a U-shaped polymetallic element **121** having a pair of legs **122, 124**, located in spaced parallelism in the same plane and having an interconnecting cross arm **126** which has a flange portion **128** for stiffening the polymetallic element **121** for the same reasons that the flange portion **110** was provided in the pulser unit **32**. The leg portion **122** of the responder **34** carries a movable contact **130** and has the operating winding **117** wound in intimate heat transfer relationship therewith. The other leg **124** of the responder unit **34** is connected to a fixed support indicated at **134**, and is also connected to ground. The contact **130** is normally open with respect to a contact **138** located relative to the U-shaped polymetallic element **121** on a cantilevered spring support arm **140** adjusted with respect to the contact **30** by a screw element **142**. Winding **117** is connected to secondary winding **62** of transformer **50** through pulser contacts **114, 116**, the body of pulser **32**, conductor **115**, and winding **117**, and thence to ground through the body of responder **34**. Thus, winding **117** receives current of a value determined by the output voltage of pulser **32** and, consequently, by the temperatures of sensers **24, 28**. This effective current is integrated by responder **34**.

At the beginning of the dryer heating action, winding **117** receives a comparatively low effective current and contacts **130, 138** remain separated. As the dryer heating action progresses, the heating effect of winding **117** progressively increases and contact **130** gradually approaches contact **138**. At a critical summed value of the resistances of sensers **24, 28**, governed jointly as aforesaid by temperature conditions in the inlet and output ducts of the dryer, contact **130** engages contact **138** and initiates actions which terminate the initial heating stage of the drying operation.

More particularly, closure of contacts **130, 138** completes a circuit which connects a timer-motor **150** across the secondary winding **62** of the transformer **50**. This circuit extends from winding **62**, through conductors **64** and **100**, motor **150**, conductor **152** and thence through contacts **130, 138** and the polymetallic element **121** to ground. When the timer-motor **150** is energized it rotates the shaft **78** in a clockwise direction through conventional reduction gearing (not shown) to drive the selector cam **88** to terminate the initial heating stage.

Before describing the terminating action in detail, it should be noted that the control system does not require the attainment of predetermined individual temperatures in the inlet or exhaust ducts **22, 23** of the dryer assembly **10**. However, when the temperatures in these two ducts rise and thereby cause the combined resistances of the thermally responsive sensers **24, 28** to reach a critical value, the effective output voltage of the pulser **32** will be sufficiently high to cause the operating winding **117** on the responder **34** to increase the temperature differential between the legs **122, 124** to cause the movable contact carrying leg **122** to deflect into engagement with the fixed contact **138**. This critical combination of inlet and exhaust temperatures might occur, for example, with a 10-pound load when the inlet temperature is 300° F. and the outlet temperature 105° F. and the corresponding dual senser resistances might be 24 and 28 ohms, respectively. By way of further example, with a 2-pound load these inlet and exhaust temperatures might be 250° F. and 135° F., respectively, and the corresponding dual senser resistances might be 18 and 34 ohms, respectively.

It is preferred that a spread or differential exist between the effective voltage at which the contacts **130, 138** will be brought into engagement and the lower voltage at which the contacts **130, 138** will be separated. In the illustrated embodiment this is accomplished by employing a magnetic circuit including a permanent magnet **144** which has pole pieces on either side of the contact **138** and a ferrous armature **145** mounted on the contact carrying end of the arm **122** transversely to the longitudinal axis thereof. The magnetic attraction between the permanent magnet **144** and the armature **145** will produce a snap-closing action of the contacts **130, 138** as the movable contact **130** moves relative to the fixed contact **138**.

More particularly, in response to an increase in the effective voltage output appearing across the operating winding **117** of the responder **34** the movable leg portion **122** heats and deflects in a direction to close the contacts **130, 138**. This closing action is supplemented by the magnetic action of the permanent magnet **144** and armature **145**. When the contact **130** is in a selected degree of proximity to the contact **138** the magnetic attraction produces a rapid movement of the contact **130** into engagement with the contact **138**. When the effective voltage drops because of reduced temperatures in the inlet and outlet ducts **22, 23** in the dryer assembly, the movable leg portion **122** of the responder will cool tending to deflect in a direction to separate the movable contact **130** from the fixed contact **138**. This separation is inhibited by the magnetic attraction between the permanent magnet **144** and the armature **145**. However, when the effective voltage reduces a sufficient amount, the contacts **130, 138** will abruptly separate.

By virtue of this construction, an adequate increase in the combination of temperatures sensed by the thermally-responsive sensers **24, 28** in the inlet and exhaust ducts **22, 23** produces (with a positive temperature coefficient of resistance senser) an increase in the effective output voltage from the pulser **32** of sufficient magnitude to produce engagement of the fixed and movable contacts **138, 130** of the responder unit **34**. These contacts will remain closed until the sensed temperatures decrease to decrease the effective voltage output from the pulser **32** to a value such that the movable contact **130** of the responder **34** will separate from the fixed contact **138** once the magnetic circuit attraction is overcome. The effective voltage output at which the fixed and movable contacts **138, 130** are opened and closed are adjusted in the illustrated arrangement, by adjusting the position of the fixed contact **138** by deflecting the spring arm **140** with the screw element **142**.

It will be appreciated that in the broader aspects of the invention various alternative arrangements may be utilized to cause the attainment of a certain combination of inlet and outlet temperatures to produce the control action attributed above to responder **34**. For example, sensers **24** and **28** might be eliminated from the circuit of pulser winding **120** and introduced instead into conductor **115** in which event pulser **32** would serve only a voltage compensating function and deliver a substantially fixed effective voltage to loads connected between contacts **114**, **116** and ground; and sensers **24** and **28** (modified to have negative temperature coefficients of resistance) would serve to progressively increase the effective current flow in winding **117** produced by the just-mentioned substantially constant effective voltage. Similarly, in its broader aspects it is within the purview of the invention to arrange the responder to cause its contacts **130**, **138** to close in response to a decrease rather than an increase in the effective current supplied to winding **117** and in such an arrangement sensers having negative temperature coefficients of resistance rather than the positive coefficient attributed above to sensers **24** and **28**, could be used in the position shown for sensers **24** and **28**. With this contact arrangement sensers having a positive coefficient of resistance could be located in the alternative position mentioned above in conductor **115**. Still other alternate relationships within the purview of the invention as defined in the claims hereof will occur to those skilled in the art.

Continuing with the description of the action which follows closure of responder contacts **130**, **138**, when timer-motor **150** is energized it turns the shaft **78** and selector cams **80**, **88** in a clockwise direction toward the starting position. The initial movement of the cam **88** forces the cam follower arm **92** out of a notch **91** on the periphery onto a land portion **90** of the cam. This moves the spring contact blade **70** away from the blade **76** to open the contacts **72**, **74** of the main heater switch and deenergize the main heater **16** terminating the heating action. Also, release of blade **76** enables it to deflect toward blade **95** and causes it to move and close contacts **95***a*. Closure of contacts **95***a* completes a self-holding circuit for motor **150**.

Interruption of heating by the main heater **16**, of course, lowers the temperature conditions in both the inlet and exhaust ducts **22**, **23** thereby reducing the resistance of the dual sensers **24**, **28** below the critical summation value. This correspondingly lowers the effective voltage output of the pulser **32** and reduces the effective voltage supplied to the operating winding **117** of the responder **34**. After a predetermined reduction in the effective voltage occurs, as mentioned above, the movable contact carrying leg **122** of the responder deflects against the attraction of the permanent magnet to a degree to cause the fixed and movable contacts **130**, **138** to snap to an open position. This opening is without an immediate effect because, as aforesaid, the timer-motor circuit holding contacts **95***a* remain closed to maintain the timer-motor in operation throughout the travel of the cam follower arm **92** across a given land portion **90** on the periphery of the selector cam **88**. The time in which the cam follower **94** remains on the land portion **90** of the selector cam **88** may be, for example, one and one-fourth minutes. At the expiration of this time, which may be the same for all intervals between heating cycles or of successively different lengths depending upon the desired control effect, the cam follower arm **92** drops into, in the present description, the fourth cycle notch thereby reclosing the main heater switch contacts **72**, **74** and slightly thereafter the movement of the contact blade **70** will deflect the spring contact blade **76** to a degree which will move the pusher **93** away from the timer-motor holding contacts **95***a* which will then open to deenergize the timer-motor **150**.

Closing of the main heater switch **66** re-energizes the dryer heater **16**. When the temperatures in the inlet and exhaust ducts **22**, **23** have risen to such an extent that the combined resistance of the thermally-responsive dual sensers **24**, **28** again equals the predetermined critical value, as for example, 52 ohms, the second heating cycle is terminated in the same manner as was described with reference to the termination of the first heating cycle.

As would be expected, the exhaust temperature will increase during the second heating cycle over the temperature obtained during the first heating cycle and, consequently, the critical summation of the resistances of the sensers **24**, **28** is reached in the second cycle at a time when the inlet temperature is somewhat lower, and the outlet temperature somewhat higher, than at the end of the first heating cycle. Moreover, throughout a succession of heating cycles the aforesaid exhaust temperature progressively rises and the inlet temperature progressively falls off, each heating cycle being terminated when the summation of the resistance value of the thermally-responsive sensers **24**, **28** corresponding to the inlet and exhaust temperatures, reaches the predetermined resistance value which may be set, by way of example, at 52 ohms.

Termination of the second heating cycle restarts the timer-motor **150** in the previously described manner and again moves the selector cams **80**, **88** in a clockwise direction toward the starting position. When the land portion on the periphery of the main heater selector cam **88** has completed its travel past the follower arm **92** the latter drops into the three-cycle notch reinitiating the heating cycle in the previously described manner. These operations continue until the control system has completed the three-cycle, two-cycle and one-cycle heating stages. Upon completion of the last heating cycle, the follower arm **92** rides upon the land portion **154** on the periphery of the main heater selector cam **88**. This relatively longer land portion **154** maintains the main heater switch **66** open to provide a cooling down period, for example, three to four minutes in which air continues to circulate through the dryer assembly without being heated as the drum **14** continues to rotate. At the expiration of the cooling down period, the selector cams **80**, **88** reach their starting positions, at which the follower arm **82** drops into the notch **84** on the selector cam **80**, thereby opening the control switch **51** and deenergizing the transformer **50** and the drum and fan motor **66**. This restores the system to the condition existing at the time dial **30** was initially set to the selected single- or multi-stage position.

The previously described voltage amplifying winding **118** portion of the pulser **32** causes given variations in the combined resistances of the dual sensers **24**, **28** to produce a greater change in the effective output voltage of the pulser **32** than would otherwise be the case and so increases the sensitivity of the system. More particularly, the winding **118**, as shown, is wound in intimate heat exchange relationship with the fixed leg **106** of the pulser and is connected to the body of the polymetallic element **102** to receive a pulse of current each time the operating winding **120** receives such a pulse. The current flows from the secondary winding **62** of the step-down transformer, through the closed contacts of the pulser **32**, the body **102** of the pulser and thence through the voltage amplifying winding **118** to ground. The voltage amplifying winding **118** is weaker than the operating winding **120** wound on the movable contact carrying leg portion **104** of the pulser, but its effect is to reduce the differential in temperature between the legs **104**, **106** of the pulser and by so doing to resist or delay the opening of the contacts **114**, **116** of the pulser. In other words, with the voltage amplifying winding **118**, energy must be supplied to the operating winding **120** at a higher rate (i.e., the ratio between closed and open periods of contacts **114**, **116** must be increased) in order to enable it to maintain the movable contact carrying arm **104** at such a temperature that the contacts **114**, **116** are in the previously described incipient opening and closing condition. Since the effective voltage between the contacts **114**, **116** and

ground is proportional to the rate at which the operating winding **120** absorbs energy, it follows that the effect of the voltage amplifying winding **118** is to increase the effective voltage between the contacts **114, 116** and ground and, consequently, to increase the effective voltage applied to the operating winding **117** of the responder unit **34**.

Furthermore, the action of the voltage amplifying winding **118** is regenerative. That is to say, a given amount of heating of the fixed leg portion **106** by the voltage amplifying winding **118** requires a given increase in the heating action of the operating winding **120** on the movable contact carrying leg **104** and a given increase in the effective voltage between the contacts **114, 116** and the ground. The last-mentioned increase acts to increase the duration of current flow through the voltage amplifying winding **118** which acts to increase the effective heating period of the fixed leg portion **106** of the pulser requiring a still further increase in the rate at which the operating winding **120** absorbs energy, and a still further increase in the effective voltage between the contacts **114, 116** and ground. In spite of this regenerative effect, the system is stable because the operating winding **120** absorbs sufficiently greater energy than the voltage amplified winding **118** to enable it, under all conditions, to eventaully cause the contacts **114, 116** to separate and maintain an incipient opening and closing relationship.

The illustrated improved control circuit also compensates for variations in ambient conditions in the dryer assembly **10** and variations in the heating effect of the main heater **16** of the dryer assembly caused by variations in the supply voltage. In operation, the air drawn into the dryer is, of course, subject to ambient conditions and, consequently, for example, increases in ambient temperature, tend to raise temperature conditions in both the inlet and exhaust ducts **22, 23**. Unless compensated, these increases in air temperatures would cause the dual sensers **24, 28** to prematurely reach their critical summed resistance value. In the present arrangement, the pulser **32** is preferably placed in an area where it is subject to these ambient changes. Generally speaking, if the legs **104, 106** of the polymetallic element **102** are of the same length (i.e., if the pulser **32** were fully compensated for ambient conditions), it would be insensitive to ambient change. In the present arrangement, the pulser **32** is slightly under-compensated, for example, by making the fixed leg portion **106** of the polymetallic element **102** slightly shorter than the movable contact carrying leg **104**. Being slightly under-compensated (for a given resistance value of the dual sensers **24, 28**) the effective voltage of the pulser **32** falls off somewhat with increases in ambient temperatures, thereby delaying the closure of the normally open responder contacts **130, 138** until the resistance of the duel sensers **24, 28** obtain values which are higher than normal by an amount sufficient to compensate for the increase in ambient temperature. This compensation occurs since at a higher ambient temperature, the movable contact carrying leg **104** has a naturally higher temperature and, consequently, less energy needs to be supplied by the operating winding **120** in intimate heat transfer contact therewith in order to bring the movable contact carrying leg **104** of the pulser **32** to the critical temperature at which the contacts **114, 116** incipiently open and close.

Another variable which, in accordance with the present invention, is preferably compensated for, is variations in voltage of the supply for the main heater **16**. These voltage variations, of course, vary the rate at which heat is supplied by the main heater **16**. For example, an increase in the heating rate of the heater **16** tends to prematurely raise the inlet and exhaust duct air temperatures and this in turn tends to cause the dual sensers **24, 28** to prematurely reach their critical summed resistance value. It is desirable that an increase in the heating rate of the heater **16** should shorten the heating intervals to some extent, but it has been found desirable to minimize or somewhat reduce the degree to which the increases in the heating rate of the heater **16** tend to shorten the heating interval. This is accomplished by a voltage compensating winding **156** wound in intimate heat transfer contact with the fixed arm portion **124** of the responder unit **34**. This winding is directly connected across the secondary winding **62** of the transformer **50** through a conductor **154**, and the body of the polymetallic element **121** to ground. Increases in the rate at which heat is supplied to the leg **124** by the voltage compensating winding **156** tend to delay closing of the contacts **130, 138** of the responder unit **34**. Therefore, though an increase in the heating rate of the main heater **16** has the net effect of shortening the heating cycles, such effect is partially and to a desired degree offset by the voltage compensating winding **156**.

While it will be apparent that the embodiment of the invention herein disclosed is well calculated to fulfill the objects of the invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. In drying apparatus, the combination of means defining a drying chamber for the material to be dried, means defining inlet and exhaust ducts communicating with said drying chamber, means for circulating air through said drying chamber and said inlet and exhaust ducts, heater means for heating the air, first resistive means for sensing the air temperature in said inlet duct, second resistive means for sensing the air temperature in said exhaust duct, thermomative switch means responsive to the combined resistance of said resistive means and effective when the temperatures jointly sensed by said first and second resistive means reaches a summed critical value to control the drying action, selector means for selecting any of a plurality of drying cycles, motor means responsive to said switch means for causing said selector means to alternately energize and de-energize said heater means during the selected drying cycle and to terminate the drying action, and voltage compensating heating means cooperating with said switch means to render actuation of said motor means directly dependent upon said critical value and insensitive to voltage changes.

2. In drying apparatus, the combination of means defining a drying chamber for material to be dried, means defining inlet and exhaust ducts communicating with said drying chamber, means for circulating air through said chamber and said inlet and exhaust ducts, heater means for heating the air, first senser means having an electrical characteristic which varies with temperature for sensing the air temperature in said inlet duct, second senser means having such an electrical characteristic for sensing the air temperature in said exhaust duct, heater control means operable between on and off positions in response to an electrical signal, pulser means for generating signals in response to the condition of said first and second sensor means conjointly and independently of voltage variations, and responder means operatively associated with said pulser means and effective when the temperatures jointly sensed by said first and second senser means reach a summed critical value to actuate said heat control means and control the drying action.

3. In drying apparatus having means defining a drying chamber for drying material during any one of a plurality of selectable drying cycles, means defining inlet and exhaust ducts communicating with said drying chamber, means for circulating air through said drying chamber and said inlet and exhaust ducts, and heater means for heating the air, a heat control system comprising heating control means for successively energizing and de-energizing said heater means during a selected drying cycle, selection means for selecting a drying cycle, first sensor means having an electrical characteristic which varies with temperature for sensing the air temperature in the inlet duct, second sensor means having an electrical characteristic which varies with temperature

for sensing the air temperature in the exhaust duct, and actuating means for said heating control means to cause successive energization and de-energization of said heater means during a drying cycle and being responsive to and controlled by the temperature jointly sensed by the first and second sensor means, the periods of de-energization being constant and the periods of energization being variable.

4. In drying apparatus having means defining a drying chamber for drying material by any one of a plurality of selectable drying cycles, means defining inlet and exhaust ducts communicating with said drying chamber, means for circulating air through said chamber and said inlet and exhaust ducts, heater means for heating the air, a heat control system comprising first resistive means for sensing the air temperature in the inlet duct in a position upstream of said heater means, second resistive means for sensing the air temperature in the exhaust duct, switch means responsive to the combined resistance of said resistive means and effective when the temperatures jointly sensed by the first and second resistive means reach a summed critical value, selector means for selecting one of said plurality of selectable drying cycles and controlling energization and de-energization of said heater means during the selected drying cycle, and motor means responsive to said switch means for causing said selector means to alternately energize and de-energize said heater means during the selected drying cycle and to ultimately terminate the drying action at the end of the selected drying cycle, the periods of energization of said heater means during the drying cycle being variable and the periods of de-energization being constant.

5. A heat control system for an electric dryer or the like having a drying chamber in the form of a rotatable drum and air inlet duct means and air outlet duct means associated therewith, an electric heating element mounted in said air inlet duct means, air circulating means for passing air over said electric heating element to said drying chamber through said air inlet duct means, and motor means for said air circulating means and said drum means, comprising a first circuit for energizing said motor means, first switch means in said circuit for controlling energization of said motor means, a second circuit for said electric heating element including said first switch means, second switch means in said second circuit for controlling energization of said electric heating element, first manually and power operable switch control means for said first switch means operable to selectively open and close said first switch means and having a single off position, second manually and power operable switch control means for said second switch means operable to selectively open and close said second switch means and having a plurality of off positions and a plurality of on positions, common manually operable setting means for said first switch means and said second switch means, common power operable setting means for said first switch means and said second switch means, third circuit means for energizing said common power operable setting means to move said first switch means and said second switch means between the on-off positions, third switch means in said third circuit means operable between on and off positions, actuating means for said third switch means including first and second sensor means connected in circuit therewith and operable to vary the ratio of on-off time of said third switch means, one of said sensor means being located in said air inlet duct means upstream of said heating element and the other of said sensor means being located in said outlet duct means, fourth switch means in said third circuit means operable between on and off positions and energizing said power operable setting means in said on position, actuating means for said fourth switch means operable in accordance with the ratio of on-off time of said third switch means to energize said power operable setting means and selectively actuating said first switch means to the off position at the end of a drying cycle and selectively actuating said second switch means between the on and off positions a variably selectable number of times until said first switch means reaches the off position whereby the heat supplied by said heating element is a function of both the temperature condition in the inlet duct means and the outlet duct means.

6. The invention as defined in claim 5 and wherein said first switch means comprises rotatable cam means and movable blade means operable thereby, the periphery of said cam means having a single off position and a continuous on surface extending therearound, said second switch means comprises second rotatable cam means and movable blade means operable thereby, the periphery of said second rotatable cam means having a plurality of on positions spaced by off surfaces, and said common manually operable setting means being movable to index said second rotatable cam means to select a particular drying cycle and said common power operable setting means being thereafter movable to index said second cam means and move said second blade means from on position to on position around the periphery of said second cam means and to simultaneously index said first cam means until said first movable blade reaches the off position.

7. In a heating system for an electric dryer or the like having a drying chamber, an electric heating element, air circulating means for passing air over said electric heating element including air inlet duct means and air outlet duct means, and motor means for said air circulating means, heat control means comprising a first circuit for energizing said motor means, first switch means in said circuit for controlling energization of said motor means, a second circuit for said electric heating element including said first switch means, second switch means in said second circuit for controlling energization of said electric heating element, first manually and power operable switch control means for said first switch means operable to selectively open and close said first switch means, second manually and power operable switch control means for said second switch means operable to selectively open and close said second switch means and having a plurality of off positions and a plurality of on positions, common manually operable setting means for said first switch means and said second switch means, third circuit means for energizing said common power operable setting means to move said first switch means and said second switch means between the on-off positions, a third switch means in said third circuit means operable between on and off positions, and actuating means for said third switch means including first and second sensor means connected in circuit therewith and operable to vary the ratio of on-off time of said third switch means, one of said sensor means being located in said inlet duct means and the other of said sensor means being located in said outlet duct means.

8. A heating system for a dryer having spaced air inlet means and air outlet means comprising heating means for heating the air entering said dryer through said air inlet means and leaving said dryer through said air outlet means, first temperature sensor means mounted in said air inlet means and second temperature sensor means mounted in said air outlet means, pulser means connected in circuit with said first and second sensor means and being operable in accordance with a joint condition of said first and second sensor means, said pulser means comprising a thermomotive member, a first heater means associated with said thermomotive member and connected in circuit with said first and second sensor means to produce a variable heat effect on said thermomotive member in accordance with the temperature conditions sensed in said dryer by said first and second senser means, responder means connected in circuit with said pulser means and being operable thereby, and control means operable by said responder means to selectively

energize and de-energize said heating means in accordance with temperature conditions existing in both the air inlet means and the air outlet means.

9. The invention as defined in claim 8 and including a second voltage amplifying heater means in heat transfer relationship with said thermomotive member.

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