April 9, 1946. R. W. SHOEMAKER 2,398,333

THERMAL-BALANCE-RESPONSIVE APPARATUS

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Fig. 1.

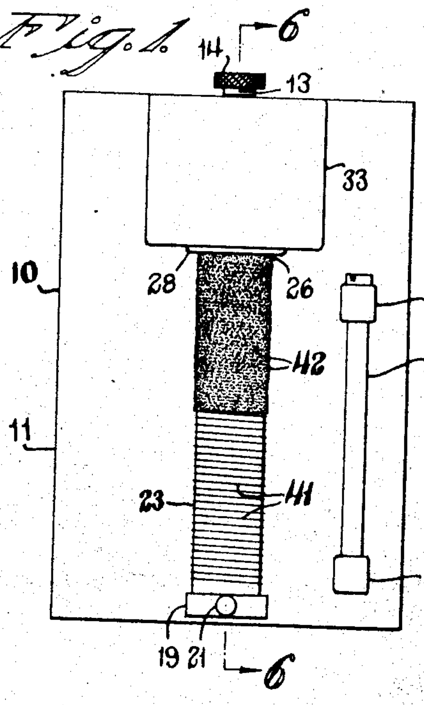


Fig. 2.

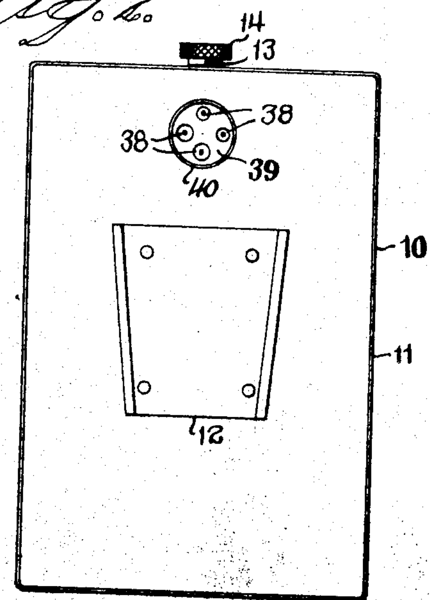


Fig. 4.

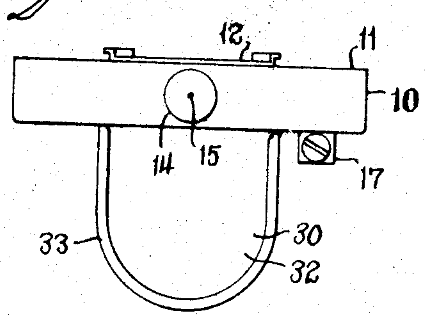


Fig. 3.

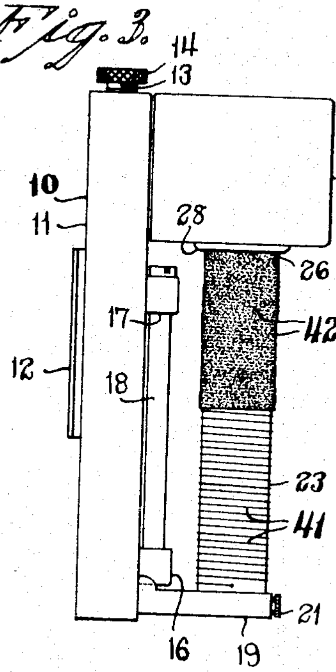
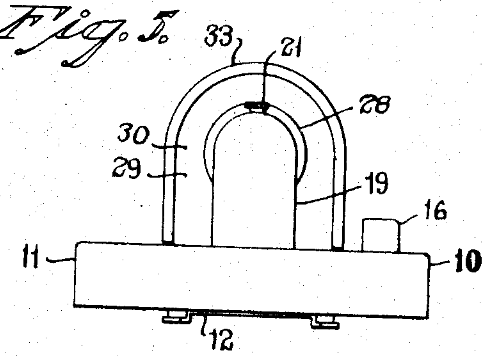


Fig. 5.



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THERMAL-BALANCE-RESPONSIVE APPARATUS

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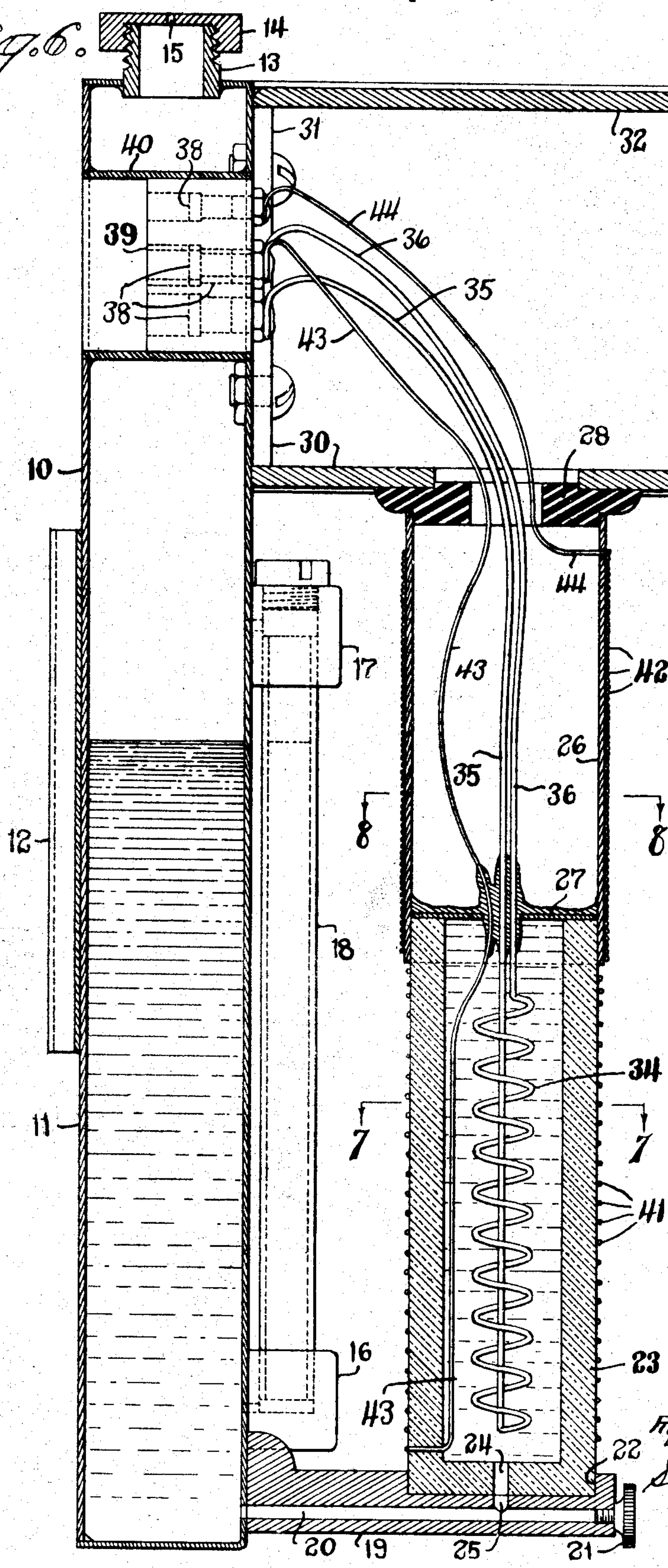
Fig. 6.



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THERMAL-BALANCE-RESPONSIVE APPARATUS

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Fig. 7.

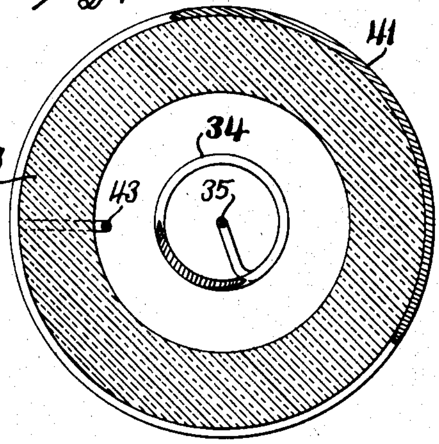


Fig. 8.

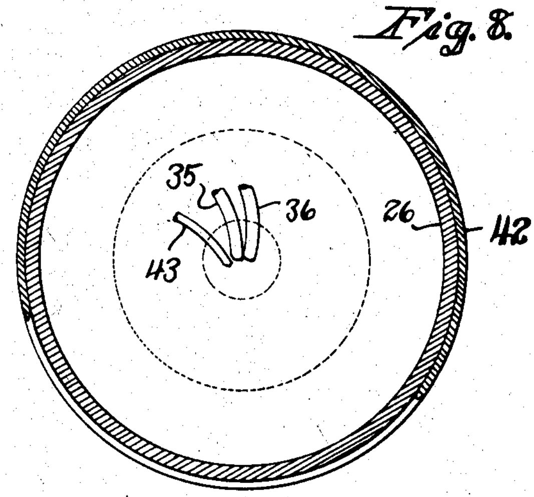
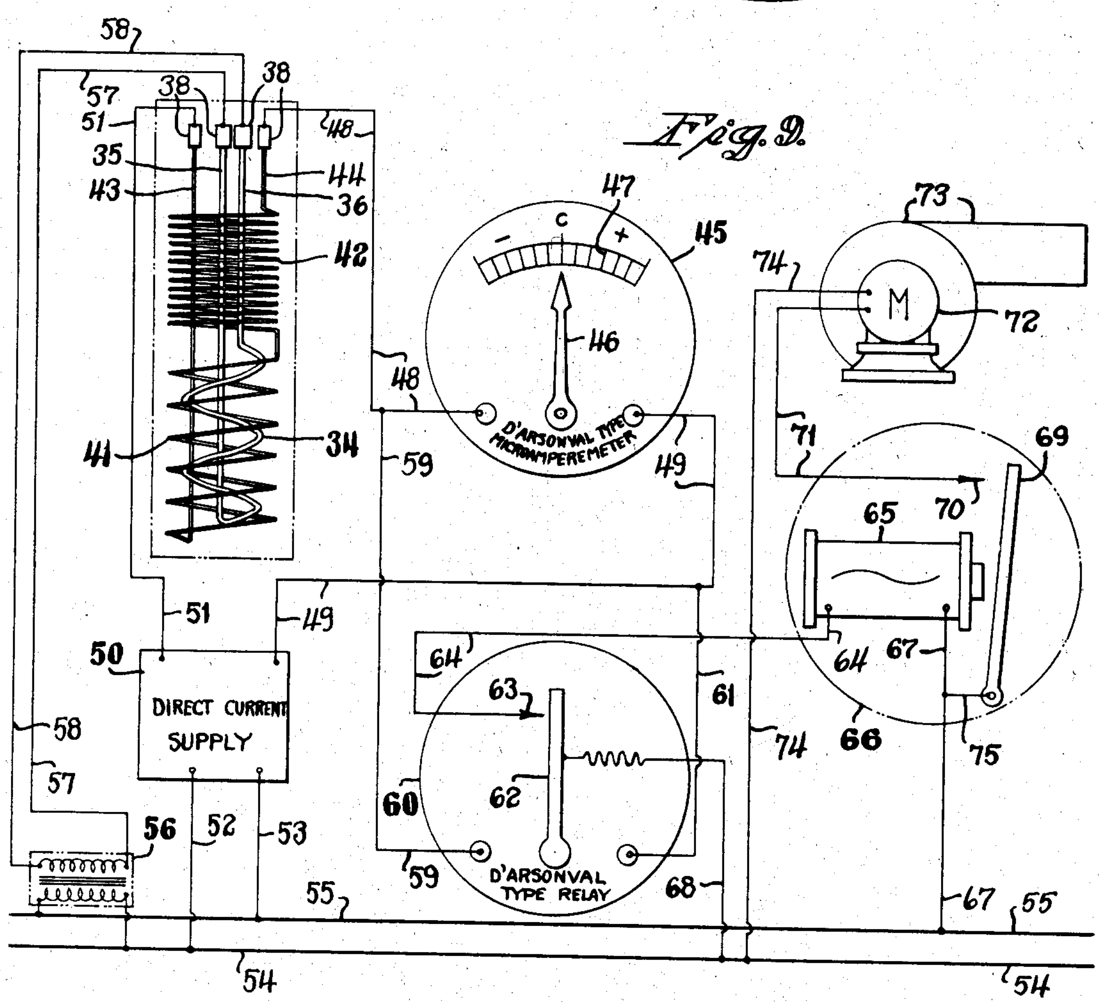


Fig. 9.



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Patented Apr. 9, 1946 2,398,333

UNITED STATES PATENT OFFICE

2,398,333

THERMAL-BALANCE-RESPONSIVE APPARATUS

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Application April 8, 1943, Serial No. 482,351

8 Claims. (Cl. 236—44)

The present invention relates to improvements in thermal-balance-responsive apparatus, i. e., apparatus which will respond to radiant heat, convective heat and latent heat of evaporation, and which will integrate the effects of all thereof into a unitary result to thereby measure, respond to, or take into account the conjoint mutually-modifying effects on human comfort of radiant heat and the other types of heat referred to.

Before proceeding with a description of one mode of carrying out the present invention, attention may here be called to the fact that while a temperature of 70° F. is normally considered to be a comfortable temperature for a room, such temperature cannot be relied upon to provide comfort for persons occupying a room when the latter is at such a temperature. One room may feel perfectly comfortable to an occupant when at 70° F. while another room with an identical temperature may feel uncomfortable to the same individual. The uncomfortable feeling in the room last referred to may be accounted for as being due to one or both of two major factors, i. e., (a) the humidity being too low and/or (b) the wall-surface temperature being lower than that required for comfort. In this connection it may be pointed out that the human body loses heat through its skin to any adjacent surface which is below the average skin-surface temperature (about 83° F.) of the person in question. When too great a surface in a room is cold (i. e., the mean radiant temperature is too low), an uncomfortable feeling will result to an occupant. In a comfortable room it will usually be found that the wall-surface temperatures are at such an average temperature as to minimize, if not nullify, radiant heat losses from the skin surface of the occupant.

As pertinent in connection with the foregoing and in connection with the discussions hereinafter appearing, it may be pointed out that factors affecting human comfort may be broadly summarized as involving air temperature, humidity, air movement, and radiation—the latter involving radiation both to and from the individual. The average man appears to lose bodily heat under average conditions at the rate of about 400 B. t. u.'s per hour when such individual is at rest. Roughly speaking, about 90 B. t. u.'s per hour of such heat loss constitute that occasioned by evaporation of bodily moisture (i. e., latent heat of evaporation), which is affected by both the moisture content and the motion of the air surrounding the person. Also, about 190 B. t. u.'s per hour are lost by the average individual due to radiation outwardly from his person, and about 120 B. t. u.'s per hour are lost by the person as a result of convection or air movement.

As will be more fully apparent from the following, the present invention is primarily designed for affecting an electrical translating-device in response to changes in the heat-factors which go to make for and which affect the bodily comfort of human beings. The electrical translating-device referred to may be of any one of a variety of types and may, for instance, visually indicate changes or serve to indicate changes in heat-factors by controlling an auxiliary or supplemental mechanism. The term "indicating" or its equivalent is, for purposes of convenience of description, used herein in the broadest sense of causing an action which is in response to changes in heat-factors affecting human comfort.

One of the objects of the present invention is to provide a superior apparatus of the character referred to whereby the effects of radiant heat upon a person may be integrated or gauged conjointly with the effects of convective heat and latent heat of evaporation on such person, to thereby take into account the major factors affecting personal comfort.

Another object of the present invention is to provide a superior thermal-balance-responsive apparatus which will visually indicate to an observer the conjoint effects of radiant heat, convective heat and the latent heat of evaporation.

A further object of the present invention is to provide a superior apparatus of the character referred to by means of which the conjoint effects of radiant heat, convective heat and latent heat of evaporation are coordinated to control heating, cooling or other desired apparatus.

Still another object of the present invention is to provide a superior thermal-balance-responsive apparatus which will respond to radiant heat, convective heat, and latent heat of evaporation in substantially the same manner as an average human being responds thereto.

With the above and other objects in view, as will appear to those skilled in the art from the present disclosure, this invention includes all features in the said disclosure which are novel over the prior art.

In the accompanying drawings, in which certain modes of carrying out the present invention are shown for illustrative purposes:

Fig. 1 is a face view of one form of detector-unit which may be employed in carrying out the present invention;

Fig. 2 is a view thereof in rear elevation;

Fig. 3 is a view of the detector-unit in side elevation;

Fig. 4 is a top or plan view thereof;

Fig. 5 is an underside view thereof;

Fig. 6 is a view in vertical central-longitudinal section taken on the line 6—6 of Fig. 1 but on a larger scale;

Fig. 7 is a transverse sectional view taken on the line 7—7 of Fig. 6;

Fig. 8 is a similar view taken on the line 8—8 of Fig. 6; and

Fig. 9 is a view schematically illustrating one form of a complete thermal-balance-responsive apparatus embodying the present invention.

The detector-unit

The apparatus shown in the accompanying drawings includes what may be aptly termed a "detector-unit" which is generally designated by the reference character 10 and which, as will hereinafter appear, is designed and adapted to detect and respond to changes in any one or all of radiant heat, convective heat and latent heat of evaporation.

The detector-unit above referred to is especially well shown in Figs. 1 to 8 inclusive and includes a block-shaped tank 11 of rectangular form in elevation and adapted to be mounted against a wall-surface of a room or other enclosed space. For purposes of convenient attachment to a wall, the back-face of the tank 11 has secured thereto a tapered attachment-plate 12 which is adapted to fit into a suitable socket (not shown) of conventional and well-known type. At its upper end, the tank 11 is provided with an externally-threaded tubular neck 13 leading to its interior and provided with a removable closure-cap 14 having a minute vent-passage 15 therein.

In the lower right-hand corner of its front wall, the tank 11 is formed with a forwardly-projecting lug 16 having a passage therein communicating with the interior of the said tank. Seated at its lower end in the lug 16 and extending upwardly therefrom into a second lug 17 is a tubular gauge-glass 18. Like the lug 16, the lug 17 has a passage therein communicating with the hollow interior of the tank 11 so that water or other fluid within the said tank will indicate a similar level in the gauge-glass 18 when the fluid-level falls to a level below the under-face of the lug 17.

Brazed or otherwise rigidly secured to the front face of the tank 11 of the detector-unit 10 is the inner end of a bracket-arm 19. The said bracket-arm is formed with a horizontal water-passage 20 communicating at its inner end with the hollow interior of the tank 11 and closed at its outer end by a screw-like drain-plug 21.

Adjacent its outer or forward end, the bracket-arm 19 is formed in its upper face with an upwardly-opening socket or recess 22 which is cylindrically contoured to receive the similarly-contoured lower end of a porous cup 23. The said porous cup may be formed of any suitable porous material, though it has been found that porous unglazed ceramic material of a character commonly used in the chemical art is suitable to discharge the function of permitting moisture to seep from the interior to the exterior of the porous cup for purposes as will hereinafter appear.

The lower end of the porous cup 23 is preferably cemented in a watertight manner in the socket or recess 22 in the bracket-arm 19 and has centrally formed in its bottom-wall a vertical water-passage 24 communicating at its lower end with a short vertical water-passage 25 formed in the bracket-arm 19 and communicating at its lower end with the horizontal water-passage 20 therein.

Sleeved over the upper end of the porous cup 23 is the lower end of a tube 26 having soldered or otherwise rigidly secured therein at a point a short distance above its lower end, a centrally-apertured transverse partition-plate 27, as is shown in Fig. 6. The tube 26 and the partition-plate 27 therein may be formed of any suitable material such, for instance, as brass.

The upper end of the tube 26 is sleeved over the lower end of a centrally-apertured head-plate 28 and is preferably cemented thereto in a moisture-tight manner. The head-plate 28 just referred to is in turn cemented or otherwise secured in the centrally-apertured lower horizontal arm 29 of a U-shaped bracket generally designated by the reference character 30. The integral vertical base-reach 31 of the U-shaped bracket 30 is skeletonized and bolted or otherwise rigidly attached to the upper-portion of the forward face of the tank 11, as is especially well shown in Fig. 6.

Extending parallel with the lower arm 29 of the bracket 30 is an integral complemental upper arm 32 having its upper face substantially flush with the upper surface of the upper wall of the tank 11. Enveloping the sides and front of the space between the upper and lower arms 29 and 32 of the U-shaped bracket 30 is a hood 33 which may conveniently be formed of sheet metal and which is retained in place on the said bracket by frictional engagement therewith so as to be readily removable when desired.

Located centrally within the porous cup 23 is a heating-coil 34 which may be formed of any suitable electro-conductive material such, for instance, as nichrome or copper wire preferably insulated by a thin but effective coating of insulating varnish. Among the many coatings available for insulating electro-conductive wires suitable for use as a heating-coil is a type of enamel known in the art as "Formvar."

The respective complemental terminal-leads 35 and 36 extend upwardly from the interior of the porous cup 23 through the aperture in the central portion of the partition-plate 27. The said complemental terminal-leads 35 and 36 of the heating-coil 34 also extend upwardly through the tube 26 and through the head-plate 28 and bracket 29, and each has its extreme end soldered or otherwise electrically coupled respectively to the forward ends of one of a group of four electric socket-sleeves 38. The said socket-sleeves 38 form a feature of a female electric coupling-member generally designated by the reference character 39 of a type well known in the electrical art. The electric coupling-member 39 is mounted with a force-fit in the forward end of a horizontal tube 40 mounted in the upper portion of the tank 11 and extending from front to rear therethrough. The respective opposite ends of the horizontal tube 40 are soldered or otherwise secured in a watertight manner to the respective rear and front walls of the tank 11.

Continuously wrapped around the respective exteriors of both the porous cup 23 and the coaxial tube 26, is a continuous electric conductor or wire formed of a suitable metal or alloy with a dense insulating layer of varnish. So-called "Formvar" has been found excellent as an insulation. Copper wire may be used as the electrical conductor, as well as other materials which have their conductivities markedly changed by changes in temperature. As before stated, the conductor referred to is continuous, but the group of convolutions thereof which are wrapped around and in contact with the outer periphery of the porous cup 23, are designated as a group by the reference character 41. For purposes of convenience of description, the group of convolutions 41 just referred to will be designated herein as the "moisture-responsive winding" for the reason that it is arranged to have its resistance affected by the evaporation of moisture from the porous cup 23, in a manner as will more fully hereinafter appear.

The group of convolutions wrapped upon the outer periphery of the tube 26 are designated by the reference character 42, and will be herein referred to as the "radiant-heat-responsive winding." The winding 42 just referred to is so designated for purposes of description inasmuch as it is constructed and arranged to mainly respond to changes in radiant heat emitted therefrom or impinging thereon from the surrounding surfaces. The winding 42 is also responsive to convective heat, all in a manner as will also hereinafter appear.

By way of example where the porous cup 23 and the tube 26 are both about 1" in external diameter, the moisture-responsive winding 41 may comprise about 25 turns of No. 29 copper wire while the radiant-heat-responsive winding 42 may comprise about 65 turns of the same size wire.

The lower end of the moisture-responsive winding 41 is passed inwardly through and sealed in the wall of the porous cup 23 to constitute a terminal-lead 43 passing upwardly adjacent the inner wall of the said cup and through the central aperture in the partition-plate 27. The upper portion of the lead 43 passes upwardly through the tube 26, head-plate 28 and lower arm 29 of the U-shaped bracket 30 and is soldered or otherwise electrically connected to one of the socket-sleeves 38 of the female electric coupling-member 39.

As before noted, the windings 41 and 42 are continuous and, therefore, in effect, the upper end of the winding 41 is integrally connected to the lower end of the winding 42, so that the two said windings are electrically in series. The end of the upper convolution of the radiant-heat-responsive winding 42 is passed inwardly through the tube 26 into the interior thereof and constitutes a terminal-lead 44 complementing the terminal-lead 43 before referred to. From the interior of the tube 26, the terminal-lead 44 passes upwardly through the head-plate 28 and the lower arm 29 of the U-shaped bracket 30 and is soldered or otherwise electrically connected to the remaining one of the four socket-sleeves 38 of the electric coupling-member 39.

The moisture-responsive unit, comprising the winding 41 and the porous cup 23, is preferably light in color to provide a light-colored exterior surface. On the other hand, the radiant-heat-responsive unit, comprising the tube 26 and the winding 42, is preferably coated with a good grade of dull black paint. By darkening the radiant-heat-responsive winding 42 and its support 26, the unit is rendered highly emissive of its own radiant heat and highly absorbtive of radiant heat impinging thereon from surrounding objects. Conversely, the light-colored moisture-responsive unit, comprising the moisture-responsive winding 41 and the porous cup 23, is relatively non-responsive to radiant heat, since as is well known in the art, light surfaces tend to reflect radiant heat.

The tank 11 may be filled with water or other suitable volatile fluid by removing the closure-cap 14 and introducing the water through the neck 13. When water or other suitable volatile fluid is introduced into the interior of the tank 11, the same will flow through the water-passages 20, 24 and 25 into the interior of the porous cup 23 for seepage outwardly through the latter.

Electrical translating-devices

In conjunction with any suitable detector-unit such, for instance, as that above described, the present invention contemplates one or more suitable electrical translating-devices, i. e., electrical devices which will translate electric current and changes thereof flowing through the windings 41 and 42 into desired indications or responses such, for instance, as visual indications, audible indications or mechanical responses.

In Fig. 9 is schematically illustrated the various coils of the before-described detector-unit 10, together with several electrical translating-devices and related apparatus.

For purposes of directly visually indicating heat conditions in the vicinity of the detector-unit 10, an electrical translating-device in the form of a D'Arsonval-type microamperemeter 45 may be employed as is shown schematically in Fig. 9. The microamperemeter 45 constitutes, in effect, an electrical measuring-instrument and, as before noted, is preferably in the form of a D'Arsonval-type moving-coil permanent-magnet instrument. The said microamperemeter 45 is provided with an electrically-movable member or pointer 46 adapted to sweep over an arcuate series of graduations 47, which latter may be spaced to represent arbitrarily-chosen units or degrees of human comfort.

Preferably and as indicated in Fig. 9, the center of the series of graduations 47 of the instrument 45, is designated with a "C" to represent comfortable heat conditions for an average individual. In the instance shown, the graduations to the left of the center graduation of the series 47 are marked with a minus sign to indicate temperature and related conditions below conditions of comfort for the average individual. Similarly, the graduations 47 to the right of the center graduation of the series 47 are marked with a plus sign to indicate heat and associated conditions which are in excess of the requirements of an average person.

As shown, one terminal of the electrical translating-device 45 is connected by means of a conductor 48 to the particular one of the four socket-sleeves 38 to which is connected the terminal-lead 44 of the radiant-heat-responsive winding 42. The remaining terminal of the instrument 45 is connected by means of a conductor 49 to one output-terminal of a direct-current-supply unit generally designated by the reference character 50. The remaining terminal of the direct-current-supply unit 50 is connected by means of a conductor 51 to the particular one of the four socket-sleeves 38 which has the terminal-lead 43 of the moisture-responsive winding 41 connected thereto.

The two input-terminals of the direct-current-supply unit **50** have connected thereto respectively conductors **52** and **53** respectively leading to complemental power-lines **54** and **55**. In the instance shown, the power-lines **54** and **55** may lead from any suitable source of alternating-current power supply such for instance, as a commercial alternating-current supply of 60-cycle 110-volt characteristics. As thus connected to the power-lines **54** and **55**, the direct-current-supply unit **50** serves to give a direct-current output and requires no detailed description or illustration herein, since such units are well known in the art.

For the purpose of energizing the heating-coil **34**, a voltage-reducing transformer generally designated by the reference character **56** is employed. In a manner well known in the art, the said transformer **56** has its primary connected to both of the power-lines **54** and **55**, and the respective terminals of its reduced-voltage secondary are connected to the said heating-coil **34** by means of conductors **57** and **58**. The said conductors **57** and **58** lead respectively to the particular pair of socket-sleeves **38** to which the respective terminal-leads **35** and **36** of the heating-coil **34** are connected.

In addition to or in lieu of the electrical translating-device **45** or its equivalent, other electrical translating-devices may be coupled to the windings **41** and **42** of the detector-unit **10** or its equivalent to respond to variations in the resistances (or conductivities) of both the moisture-responsive winding **41** and the radiant-heat-responsive winding **42**. By way of example and as is indicated in Fig. 9, the conductor **48** leading to one terminal of the instrument **45** may have connected to it a conductor **59** leading to one terminal of a D'Arsonval-type relay generally designated by the reference character **60**. The remaining terminal of the relay **60** may be connected by a conductor **61** to the conductor **49**.

Like the D'Arsonval-type microamperemeter **45** before described, the relay **60** is also provided with an electrically-movable member **62** which latter is in the form of a contact-arm rather than in the form of a pointer, as is the case with the part **46**. The said contact-arm **62** is adapted to engage with a normally-stationary contact **63** which is connected by a conductor **64** to one terminal of an electromagnet **65** forming a feature of a relay generally designated by the reference character **66**. The remaining terminal of the electromagnet **65** is connected by means of a conductor **67** to the power-line **55** before referred to. The contact-arm **62** is itself connected by a conductor **68** to the complemental power-line **54**.

The electromagnet **65** of the relay **66** is preferably of sufficiently-high resistance to limit the current flow through the circuit of which it forms a part to a value sufficiently low to be readily handled by the sensitive and relatively-delicate D'Arsonval-type relay **60**.

In addition to its electromagnet **65**, the relay **66** also includes a pivotal contact-arm **69** and a normally-stationary contact **70**. In the instance shown, the normally-stationary contact **70** is connected by a conductor **71** to one terminal of an electric motor **72** forming the driving-unit of a fuel-oil burner **73**. The remaining terminal of the motor **72** is connected by a conductor **74** to the power-line **54**. The contact-arm **69** of the relay **66** is connected by a conductor **75** to the conductor **67**, which latter is connected into the power-line **55**, as before described.

Operation

It should here be noted that in order to secure the most accurate performance from the apparatus, the voltages applied thereto should be maintained at constant predetermined values in any suitable manner.

When the tank **11** is filled or substantially filled with water, the porous cup **23** will have water supplied to its interior, and such water will seep slowly outwardly to the exterior periphery of the said porous cup. The heating-coil **34** is so constructed and arranged as, when energized, to maintain the water in the porous cup **23** at a temperature substantially corresponding to the average skin-surface temperature of the average human being or approximately 83° F. When the current-supply is turned on through the direct-current-supply unit **50**, current will flow through the series-connected windings **41** and **42** and through both the electrical translating-devices **45** and **60**.

Under the conditions above referred to, the moisture-responsive winding **41** will have its temperature and hence its conductivity affected by the evaporation of moisture from the surface of the porous cup **23**, i. e., when the air surrounding the detector-unit **10** is relatively dry, moisture will evaporate at a relatively-rapid rate from the surface of the porous cup and thereby cool the winding **41** and thereby improve its conductivity, while conversely, should the atmosphere surrounding the detector-unit **10** be relatively humid, a relatively-small amount of evaporation will take place from the surface of the porous cup **23** with the result that the cooling effect on the winding **41** will be relatively small.

In addition to being affected by evaporation from the porous cup **23**, the moisture-responsive winding **41** will also have its temperature (and hence its conductivity) affected by the motion and the temperature of the surrounding air.

Also under the conditions above described, the radiant-heat-responsive winding **42** will receive heat by convection from the winding **41** and its associated mounting so that the conductivity of the winding **42** will be somewhat affected thereby. As before noted, the radiant-heat-responsive winding **42** and the outer periphery of the tube **26** is preferably blackened to heighten both the receptivity and emissivity thereof with respect to radiant heat.

In accordance with the well-known law developed by Stefan Boltzmann relative to radiant heat, a surface either absorbs or loses radiant heat to the surrounding surfaces when its temperature is less or greater respectively than such surfaces. From this it follows that when the temperature of the unit comprising the tube **26** and the radiant-heat-responsive winding **42** is less than the temperature of surrounding wall surfaces or the like, the said unit will absorb radiant heat and thereby have its temperature raised with the result that the conductivity of the winding **42** will be lessened. Conversely, should the temperature of the wall surfaces or the like surrounding the detector-unit be lower than the temperature of the winding **42** and its supporting-tube **26**, the said parts will radiate heat outwardly to the cooler surroundings in an effort to reach equilibrium and thereby lower the temperature of the winding **42** and hence increase its conductivity.

Now inasmuch as the joint conductivity of the windings **41** and **42** is modified by the respective temperatures of the said windings, it follows that the electrical translating-instruments **45** and **60** or their equivalents will have their respective electrically-movable members shifted one way or the other in response to any increase or decrease in the current-flow through the said coils **41** and **42**.

Inasmuch as the detector-unit **10** is so constructed and arranged that the conductivity of the windings **41** and **42** responds to changes in any or all of radiant heat, convective heat and latent heat of evaporation (which latter is, in turn, affected by the humidity of the surroundings), the detector-unit responds to conditions in substantially the same manner as the human body. These responses of the detector-unit are, in turn, translated by the instruments **45** and **60** into visual and mechanical indications or actions, respectively.

In the instance shown, the translating-device **45** is so calibrated that its pointer **46** will occupy a central position in registry with the symbol "C" indicating average human comfort when the combined effects of air motion, humidity and radiation are such as to be comfortable to an average person occupying the same space as the detector-unit **10**. The translating-device **60** is, in the instance shown, so constructed and arranged that should the combined effects of humidity, air motion and radiation be such as to cause an average human being to feel chilly, the joint conductivity of the windings **41** and **42** will increase thereby permitting a greater current-flow therethrough as well as through the instrument **60**. An increase in the current-flow, as just referred to, will cause the contact-arm **62** to engage with the contact **63**. When the contact-arm **62** engages with the contact **63**, the electromagnet **65** of the relay **66** will be energized to thus cause the pivotal contact-arm **69** to move into engagement with the contact **70**. The engagement of the contact-arm **69** with the normally-stationary contact **70** will close a circuit through the motor **72** of the fuel-oil burner **73** and thereby start the said burner to restore comfortable conditions. Upon the restoration of comfortable heat conditions, the conductivities of the windings **41** and **42** will lessen, to thereby cause the contact-arm **62** to move away from the contact **63** and thus deenergize the electromagnet **65** of the relay **66**. The stoppage of current-flow through the electromagnet **65** will, in turn, cause the contact-arm **69** to disengage itself from the contact **70** and thereby cut off the energy supply to the motor **72** of the fuel-oil burner **73**.

From the foregoing it will be seeen that either or both of the electrical translating-devices **45** and **60** respond to changes in conductivities of the respective windings **41** and **42**. It will be further apparent that the conductivity of the circuit of which the windings **41** and **42** form a part will be varied in accordance with variations in convective heat, radiant heat and latent heat of evaporation, the effects of the various types of heat being integrated in their effects upon the conductivity of the circuit and hence in their effects upon the translating-devices.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

I claim:

1. A thermal-balance-responsive apparatus including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid and having a porous wall through which such fluid evaporates, and an electrical conductor extending around the porous wall of the said evaporator-means and positioned to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid passing through the pores of the said porous wall; and an electrical translating-device electrically connected to the respective electrical conductors of both of the aforesaid units and constructed and arranged to respond to variations in the respective intrinsic conductivities of the said electrical conductors as the temperatures thereof change in response to changes in conditions surrounding the two said units.

2. A thermal-balance-responsive apparatus, including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid and having a porous wall through which such fluid evaporates, and an electrical conductor extending around the porous wall of the said evaporator-means and positioned to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid passing through the pores of the said porous wall; an electrical translating-device electrically connected to the respective electrical conductors of both of the aforesaid units and constructed and arranged to respond to variations in the respective intrinsic conductivities of the said electrical conductors as the temperatures thereof change in response to changes in conditions surrounding the two said units; and electrical heating-means located within the said evaporator-means to heat the volatile fluid contained in the evaporator-means of the said moisture-responsive unit before such fluid passes through the porous wall thereof to substantially the skin-surface temperature of the average person.

3. A thermal-balance-responsive apparatus, including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid, and an electrical conductor associated with the said evaporator-means and electrically connected in series with the electrical conductor of

the said radiant-heat-responsive unit so that current flowing through one of the said conductors must also flow through the other thereof, the electrical conductor of the said moisture-responsive unit being positioned to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid from the said evaporator-means; an electrical translating-device electrically connected to the respective electrical conductors of both of the aforesaid units in such manner that the current affecting the translating-device passes in sequence through both of the aforesaid series-connected conductors, the said translating-device being constructed and arranged to respond to variations in the respective mutually-modifying conductivities of the said electrical conductors as the temperatures thereof change in response to changes in conditions surrounding the two said units; and electrical heating-means constructed and arranged to heat the volatile fluid contained in the evaporator-means of the aforesaid moisture-responsive unit to a temperature substantially corresponding to the skin-surface temperature of the average person.

4. A thermal-balance-responsive apparatus, including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid, and an electrical conductor associated with the said evaporator-means and electrically connected in series with the electrical conductor of the said radiant-heat-responsive unit so that current flowing through one of the said conductors must also flow through the other thereof, the electrical conductor of the said moisture-responsive unit being positioned to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid from the said evaporator-means, the said moisture-responsive unit being located adjacent the lower end of the said radiant-heat-responsive unit to transfer heat to the latter by convection; an electrical translating-device electrically connected to the respective electrical conductors of both of the aforesaid units in such manner that the current affecting the translating-device passes in sequence through both of the aforesaid series-connected conductors, the said translating-device being constructed and arranged to respond to variations in the respective mutually-modifying conductivities of the said electrical conductors as the temperatures thereof change in response to changes in conditions surrounding the two said units; and electrical heating-means constructed and arranged to heat the volatile fluid contained in the evaporator-means of the aforesaid moisture-responsive unit to a temperature substantially corresponding to the skin-surface temperature of the average person.

5. A thermal-balance-responsive apparatus, including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid, and an electrical conductor associated with the said evaporator-means and electrically connected in series with the electrical conductor of the said radiant-heat-responsive unit so that current flowing through one of the said conductors must also flow through the other thereof, the electrical conductor of the said moisture-responsive unit being positioned to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid from the said evaporator-means; an electrical translating-device electrically connected to both of the series-connected electrical conductors of the aforesaid units in such manner that the current affecting the translating-device passes in sequence through both of the aforesaid series-connected conductors, the said translating-device having an electrically-movable member constructed and arranged to shift in response to variations in the respective mutually-modifying conductivities of the said electrical conductors as the temperatures of the same change in response to changes in conditions surrounding the two said units; and electrical heating-means constructed and arranged to heat the volatile fluid contained in the evaporator-means of the aforesaid moisture-responsive unit to a temperature substantially corresponding to the skin-surface temperature of the average person.

6. A thermal-balance-responsive apparatus, including in combination: a radiant-heat-responsive unit including an electrical conductor having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the unit from its surroundings or emitted by the unit to its surroundings; a moisture-responsive unit exposed to the humidity of the surrounding air and including evaporator-means for containing and evaporating a volatile fluid, and an electrical conductor associated with the said evaporator-means and electrically connected in series with the electrical conductor of the said radiant-heat-responsive unit so that current flowing through one of the said conductors must also flow through the other thereof, the electrical conductor of the said moisture-responsive unit being positioned to have its temperature and hence it intrinsic conductivity altered by variations in the evaporation-rate of fluid from the said evaporator-means, the said moisture-responsive unit being located adjacent the lower end of the said radiant-heat-responsive unit to heat the latter by convection; an electrical translating-device electrically connected to both of the series-connected electrical conductors of the aforesaid units in such manner that the current affecting the translating-device passes in sequence through both of the aforesaid series-connected conductors, the said translating-device having an electrically-movable member constructed and arranged to shift in response to variations in the respective mutually-modifying conductivities of the said electrical conductors as the temperatures of the same change in response to changes in conditions surrounding the two said units; and electrical heating-means constructed and arranged to heat the volatile fluid contained

in the evaporator-means of the aforesaid moisture-responsive unit to a temperature substantially corresponding to the skin-surface temperature of the average person.

7. A thermal-balance-responsive apparatus, including in combination: a fluid-tank; a moisture-responsive unit including a porous fluid-container located exteriorly of the said fluid-tank and having its interior in communication with the interior of the said fluid-tank, a moisture-responsive electrical winding encircling the exterior of the said porous fluid-container in position to have its temperature and hence its intrinsic conductivity altered by variations in the evaporation-rate of fluid from the said porous fluid-container; a radiant-heat-responsive unit connected to the upper end of the porous fluid-container of the said moisture-responsive unit and including an electrical winding having a surface highly emissive and highly absorbent of radiant heat and constructed and arranged to have its temperature and hence its intrinsic conductivity altered by variations in radiant heat received by the radiant-heat-responsive unit from its surroundings or emitted thereby to its surroundings; an electrical translating-device electrically connected to the respective electrical windings of both of the aforesaid units in such manner that the current affecting the translating-device passes in sequence through both of the aforesaid series-connected conductors, the said translating-device being constructed and arranged to respond to variations in the respective intrinsic conductivities of the said electrical windings as the temperatures thereof change in response to changes in conditions surrounding the two said units; and an electrical heater positioned within the porous fluid-container of the said moisture-responsive unit to heat the volatile fluid contained therein to a temperature approximating that of the skin-surface temperature of the average person.

8. A moisture-responsive apparatus including in combination: a fluid-container for containing a volatile fluid and having a porous wall through the pores of which the contained fluid is evaporated; an electrical conductor encircling the porous wall of the said fluid-container and closely contacting the same in such manner as to have its temperature and hence its electrical conductivity altered by variations in the evaporation rate of the fluid through the porous wall of the said fluid-container; and an electrical translating device electrically connected to the said electrical conductor and constructed and arranged to respond to variations in the electrical conductivity of the said electrical conductor as the temperature thereof changes in response to changes in the evaporation rate of the volatile fluid contained by the said fluid container.

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