Nov. 23, 1948. J. HORNBOSTEL 2,454,320

HYGROMETER AND SWITCH FOR RADIOSONDES

Filed May 15, 1943 2 Sheets-Sheet 1

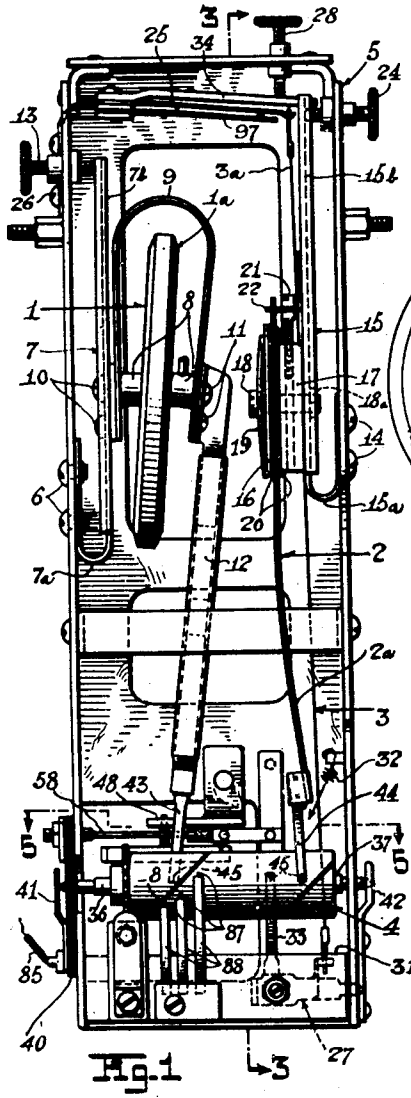


Fig. 1

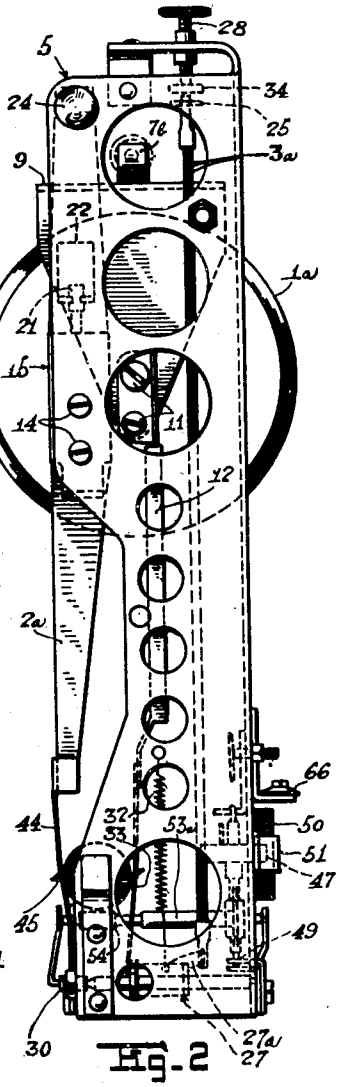


Fig. 2

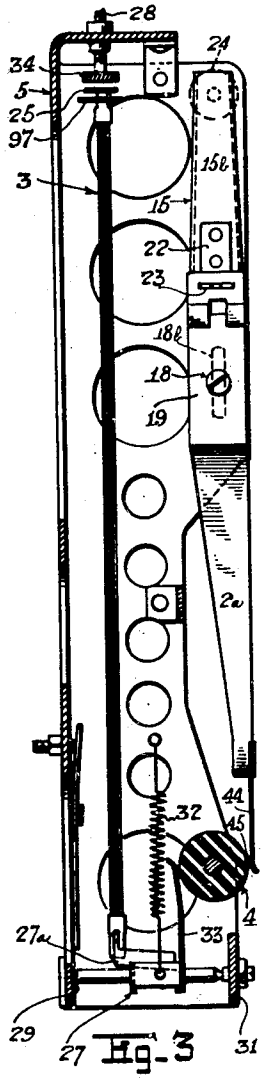


Fig. 3

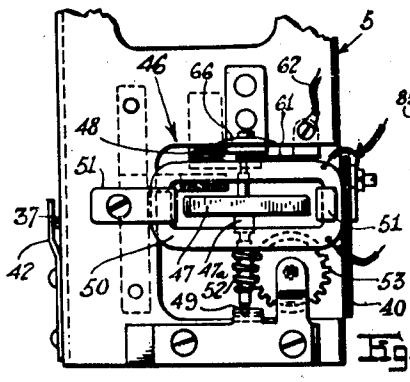


Fig. 4

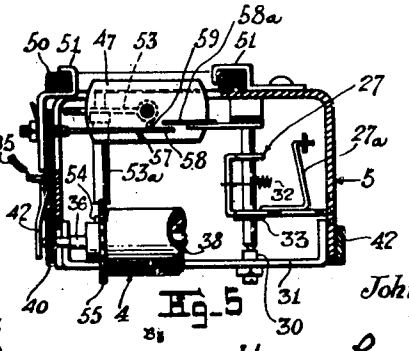


Fig. 5

Inventor
John Hornbostel
Henry Lanahan
Attorney

Nov. 23, 1948. J. HORNBOSTEL 2,454,320

HYGROMETER AND SWITCH FOR RADIOSONDES

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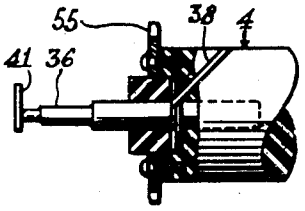


Fig-6

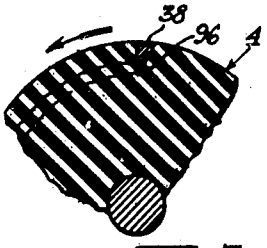


Fig-7

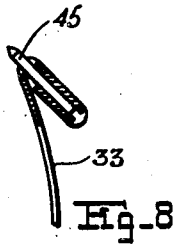


Fig-8

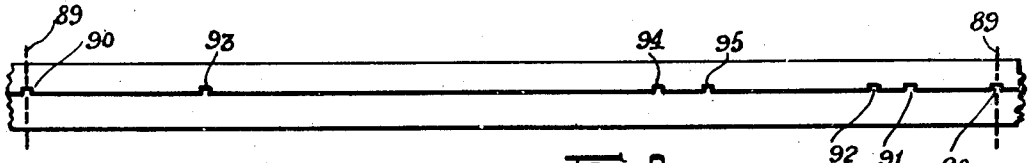


Fig-9

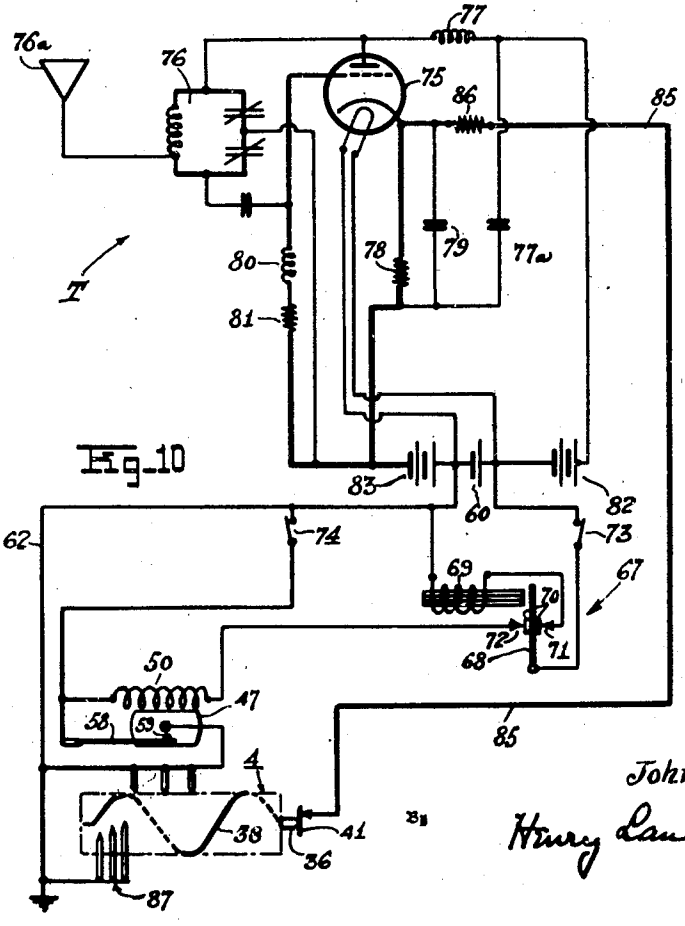


Fig-10

Inventor
John Hornbostel
Henry Lanahan
Attorney

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UNITED STATES PATENT OFFICE

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HYGROMETER AND SWITCH FOR RADIOSONDES

John Hornbostel, Glen Ridge, N. J., assignor to Thomas A. Edison, Incorporated, West Orange, N. J., a corporation of New Jersey

Application May 15, 1943, Serial No. 487,425

8 Claims. (Cl. 200—52)

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This invention relates to radiosondes and more especially to improvements in radiosondes of the chronometric type.

The general objects of my invention are to provide a radiosonde of this type which is capable of great accuracy of measurement, which is easy to calibrate and which is simplified in various features of its construction.

It is a further object to provide improvements in radiosonde measuring instruments to facilitate their construction, adjustment and control.

Another object is to provide a strong rigid mounting for a radiosonde instrument which is simple in construction and adapted to permit ready adjustment of the instrument to a zero-indicating position.

Another object is to provide an improved hygrometer for a radiosonde which is compensated for variations in temperature.

Another object is to provide improvements in the construction of chronometric-type contactor devices for radiosondes.

A further object is to provide an improved drive mechanism for radiosonde contactor devices and especially a motor system for a radiosonde which is simple and light in construction and capable of maintaining a highly constant speed.

These and other objects of my invention will more fully appear from the following description and the appended claims.

In the description of my invention reference is had to the accompanying drawings, of which:

Figure 1 is a front elevational view of a radiosonde mechanism incorporating my invention;

Figure 2 is a right-hand side elevational view of the mechanism of Figure 1;

Figure 3 is a vertical sectional view taken on the line 3—3 of Figure 1;

Figure 4 is a rear view of the lower portion of the mechanism of Figure 1, showing the drive motor for the radiosonde;

Figure 5 is a horizontal sectional view taken on the line 5—5 of Figure 1;

Figure 6 is a fractional view of the rotating contactor, or contactor drum as it is hereinafter referred to, of the radiosonde showing a portion in section on the axis of the drum;

Figure 7 is a fractional sectional view of the contactor drum of Figure 6, taken at right angles to the rotational axis of the drum;

Figure 8 is a view, partly in section, of the indicating finger and contact pin for the respective measuring instruments of the radiosonde;

Figure 9 is a record for one time cycle of the radiosonde; and

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Figure 10 is a diagrammatic view of the mechanism and circuits, including the radio transmitter, of the radiosonde.

It will be understood that the radiosonde mechanism shown in Figures 1 to 5 inclusive and the radio transmitter T shown schematically in Figure 10 are to be carried aloft to measure the atmospheric conditions at high altitudes. In the present illustrative example of my invention, the radiosonde includes three meteorological measuring instruments: an aneroid barometer 1, a bimetal-type thermometer 2 and a hair hygrometer 3. Operating in conjunction with these measuring instruments is a rotating contactor drum 4 which serves to key the radio transmitter at varying intervals according to the deflections of the respective measuring instruments. At the ground station a recorder is operated by the keyed radio signals to produce a chronographic record such for example as is shown in Figure 9. By a calibration of the radiosonde, this record is interpreted into definite measurements of atmospheric pressure, temperature and humidity.

The radiosonde mechanism has a channel frame 5 which is suitably apertured for reduction in weight. This frame is made of a light strong metal such as aluminum, but may instead be made of any suitable plastic. Secured by screws 6 to the left wall of the frame as it appears in Figure 1 is a vertical support member 7 for the barometer 1. This barometer comprises an aneroid capsule 1a having studs 8 rigidly secured to and projecting from its movable walls. The capsule is substantially evacuated of gas but the studs are bridged by a flat curved spring 9 which urges the walls apart and tends to hold the capsule in an expanded condition. One of the studs 8 is rigidly secured by the screws 10 to the support member 7, while the other is rigidly connected by screws 11 to an indicating arm 12. Upon a change in barometric pressure, the walls of the capsule move relative to each other and the indicating arm 12 is deflected laterally of the frame, axially along the contactor drum 4, according to the amount of change in the barometric pressure.

Adjustment of the barometer to zero is made by tilting it relative to the frame 5. For this purpose the support member 7 has a flat curved extension 7a forming a spring-hinged connection of the member to the frame, the vertical part 7b of the support member to which the barometer is fastened being made rigid by flanges turned over at the sides. By biasing the hinged part 7a the rigid part 7b of the support member is urged

strongly in a counterclockwise direction against an adjusting screw 13 in the side wall of the frame. By means of this screw the barometer is tilted and brought to zero, as will hereinafter appear.

A feature in the design of this barometer construction lies in having the spring 9 connected rigidly to the studs 8. This has the advantage of markedly simplifying the construction of the barometer. While in this construction the opposite walls of the capsule are placed under some distortion by the constraining influence of the spring 9, I find that this distortion does not impair the sensitivity and accuracy of the barometer.

Secured by screws 14 to the right wall of the frame is a support member 15 for the thermometer 2; this support member, like that for the barometer, has a vertical part 15b made rigid by flanges at the sides and a flat curved part 15a which spring-hinges the rigid part to the frame. The thermometer has a bimetal arm 2a as its active element. The upper end portion of this bimetal arm is clamped yieldably between a clamping plate 16 and block 17, and this assembly is in turn clamped yieldably to the rigid part 15b of the support member, with the block between the bimetal arm and support member. This clamping arm is done by a screw 18 and a flat bowed spring 19 interposed between the head of the screw and the clamping plate 16, the screw being fastened to the support member by nut 18a. For thermal insulation of the bimetal arm from the clamping plate and block there are interposed thin insulating plates 20. In this clamped assembly, the plates 16 and 20, and block 17 have clearance holes receiving the screw 18, but the bimetal arm and support member have vertical slots 18b through which this screw passes. Thus, the plates 16 and 20 and block 17 are frictionally held in place by the yieldable clamping pressure of screw 18 and spring 19 and may be adjusted vertically as a unit relative to the bimetal arm and support. This adjustment is finely made by a screw 21 that threads into the upper end portion of the block 17 and is anchored rotatably to the support member 15 by a bracket 22, this bracket also extending through a hole 23 in the upper end portion of the bimetal arm to hold the arm stationary as the adjustment is made. Thus, as adjusting screw 21 is turned in one direction or another the plates 16 and 20 and block 17 are moved vertically, with the screw 18 moving in the slots 18b of the bimetal arm and support member. This adjusting means is for the purpose of varying the free length of the bimetal arm to correct for variations in the sensitivity of the arms in production. By holding the bimetal arm stationary as this adjustment is made the engagement of the arm with the contactor drum 4 is not disturbed as will hereinafter appear.

Upon a change in atmospheric temperature, the bimetal arm is deflected laterally of the frame, axially along the contactor drum 4, according to the amount of temperature change. Under pressure from a biasing of the spring-hinged part 15a of the support member for the thermometer, the rigid part 15b is urged clockwise against an adjusting screw 24 in the side wall of the frame. By means of this adjusting screw the thermometer is tilted relative to the frame and brought to zero.

At the top of the radiosonde mechanism there is a horizontal cantilever spring 25 held by screws 26 to the side wall of the frame. Attached to the free end of the spring 25 are the upper ends of the strands 3a of the hair hygrometer 3, the spring forming part of an adjustable hinged support for the hygrometer as will hereinafter appear. These strands hang down through the height of the frame and are attached at their lower ends to an arm 27a of a bell crank lever 27. This lever is pivoted between a fixed thrust bearing 29 on the back wall of the frame 5 and an adjustable thrust bearing 30 on a bracket 31 at the front of the frame, this bracket being secured at its ends to the two side walls of the frame. Connected between the lever 27 and the frame is a tension spring 32 which serves to place the strands 3a under a slight tensioning. On this lever there is an upstanding spring finger 33 for indicating purposes. Upon changes in relative humidity the strands 3a vary in length and produce an angular deflection of this indicating finger in directions lateral to the frame and axially along the contactor drum.

At the top of the frame there is an adjusting screw 28 that abuts against a short horizontal bar 34 clamped to the spring 25 near the base thereof. On adjustment of the screw, the spring 25 is flexed relative to the frame to raise and lower the strands 3a and, accordingly, to turn the bell crank lever 27. This has the purpose of adjusting the hygrometer to zero.

At the lower front portion of the frame 5 is the rotating contactor drum 4. This drum comprises a cylindrical body of insulating material, such as of Bakelite, having separate spindles 36 and 37 at its ends which journal to the side walls of the frame 5. Embedded into the surface of the drum is a spiral wire 38 made for example of silver. The right end of the wire is electrically open, but the left end is connected to the left spindle 36, this spindle serving as an element for making permanent electrical connection to the wire. For this reason the left spindle is journalled insulatedly to a Bakelite plate 40 on the frame 5. Electrical connection to the spindle 36 is made by a spring conductor 41 which is mounted on the Bakelite plate 40 to bear against the end of the spindle, the thrust exerted on the drum by this spring being taken up by a thrust bearing 42 on the frame for the right spindle 37.

Secured to the indicating arm 12 of the barometer 1 and to the bimetal arm 2a of the thermometer 2 are downwardly extending spring fingers 43 and 44. These fingers, and the indicating finger 33 of the hygrometer, are apertured to receive contact pins 45, and are then bent back on themselves and welded to the pins to form firm settings for the pins. The contact pins bear against the periphery of the contactor drum under pressure of the repective spring fingers and are moved axially along the drum by the measuring instruments respectively in response to changes in atmospheric conditions. These contact pins are connected electrically to the frame through the structures of the respective measuring instruments. For purposes of explanation the potential of the frame is herein considered as a reference or ground potential, and it is this potential that is so indicated by the ground designation in Figure 10. Thus, as the contactor drum is rotated, each measuring instrument will momentarily ground the drum wire once during each revolution, but the point in each revolution at which the respective instrument so grounds the wire will depend upon the immediate deflection of that instrument. This

momentary grounding of the contactor wire serves to key the radio transmitter T, as is hereinafter explained.

The contactor drum 4 is driven by a D.-C. motor 46. This motor comprises a rotor magnet 47 journalled on a vertical axis between bearings 48 and 49, and a rectangular air-cored field coil 50 mounted in a vertical plane to one side of the rotor axis and held to the frame by clamping members 51. The rotor magnet is made of a highly efficient and coercive magnetic material such as that known commercially as "Alnico." For coupling the rotor magnet to the drum 4 there is a gear system comprising a worm gear 52 on the shaft 47a of the rotor; an intermediate gear 53 mounted on a horizontal shaft 53a and meshing with the worm gear 52; and a worm gear 54 mounted on the horizontal shaft 53a and meshing with a gear 55 that is secured to the left end of the contactor drum. As typical values, the worm gear system may have a step-down transmission ratio of 512 and the motor may have a speed of 1950 R. P. M. so as to turn the drum at a speed of approximately 3.8 R. P. M.

The motor includes an interrupter 57 in series with its field coil which comprises a spring arm 58 mounted insulatedly on the Bakelite plate 40 and a contact pin 59 that is carried by and electrically connected to the rotor magnet 47. Electrical power for the motor is supplied by a battery 60, the supply circuit from the battery to the motor being completed by way of the motor shaft 47a through a spring 61 to the frame 5 and a lead 62 which connects the frame to one side of the battery. The interrupter 57 is adapted to close the field circuit during approximately one-quarter of each revolution at the time when the field coil is capable of exerting its greatest torque (in one direction) on the magnet, this being the range in which the magnet is plus and minus approximately 45° from a position of parallelism with the plane of the coil. When the magnet is beyond this range, and the pin 59 is out of contact with the spring arm 58, the arm rests against an adjustable insulated stop 58a. During standstill the magnet is held parallel to the coil by a stationary permanent magnet 66 mounted on the frame as is shown in Figure 4. Thus, when electrical power is supplied to the field coil, a maximum starting torque is exerted on the magnet and self-starting of the motor is assured.

In radiosondes of the chronometric type it is very important that the contactor drum be turned at a constant speed. In the present motor system, the running speed of the motor is established and held highly constant, by a vibrator 67 which itself interrupts the field circuit of the motor at a fixed predetermined frequency. The vibrator comprises a tuned reed 68 and a field coil 69. The reed has a pair of spring-mounted contacts, generally referred to as 70, which make and break alternately with a pair of fixed contacts 71 and 72, the reed touching both of these contacts on standstill. The circuit of the vibrator coil is completed with the battery 60 by way of the reed and one of these fixed contacts, and the field circuit of the motor is completed by way of the reed and the other of these fixed contacts, each of these circuits however including an on-off switch 73. On closing the on-off switch 73 the reed is vibrated at its tuned frequency, which it is adapted to maintain with a high degree of accuracy. At the same time the motor starts running and acquires a speed at which its own interruptions (of the interrupter 57) are synchronized with the interruptions of the vibrator. The motor speed is thus held fixed with the same high degree of constancy with which the reed maintains its tuned frequency. The motor will however have some tendency to hunt, but I find that this hunting tendency is very greatly mitigated by shorting out the interrupter 57 of the motor once the motor has reached synchronism with the vibrator; this is accomplished by closing the switch 74 shown in Figure 10.

The radio transmitter T of the radiosonde comprises a conventional single-stage radio frequency oscillator. The oscillator circuit includes a tube 75, typically a triode of the acorn class, having a tank circuit 76 connected from its grid to plate, an aerial 76a leading from the tank circuit, a high-frequency choke 77 and a by-pass condenser 77a in its plate circuit, and a self-biasing resistor 78 and by-pass condenser 79 in its cathode circuit, the grid being returned to the low side of the cathode-biasing resistor through a high-frequency choke 80 and resistor 81. Heater current is supplied by the aforementioned battery 60, and plate current by batteries 82, 60 and 83, these batteries being connected serially in the order mentioned and all poled alike, with the battery 83 being connected between the frame potential—the low side of battery 60—and the point of junction of the grid return circuit with the cathode resistor 78. The battery 83 thus contributes to the over-all plate voltage supply and also serves as a voltage source for interrupting the oscillator for keying purposes. This is accomplished by momentarily connecting the cathode of tube 75 through a resistor 86 to the frame potential, the effect of which is to use the potential of battery 83 to so increase the grid bias relative to the cathode potential as to choke the oscillator. This momentary connecting of the cathode is made by the respective measuring instruments, as they contact the wire 38 of the drum, by way of a circuit 85 which connects the wire 38 through resistor 86 to the cathode, the resistor 86 being here used for consuming such part of the voltage of the battery 83 as may be in excess of that needed to choke the oscillator.

In addition to the moving contact pins 45 of the respective measuring instruments there are three fixed contact pins 87. These fixed contact pins are connected permanently to the frame 5 and pressed against the periphery of the drum 4 by their respective mounting springs 88, they being set into these springs in the manner aforedescribed and shown in Figure 8. These fixed contact pins are so-called reference contacts; they are set so as to contact the contactor wire 38 of the drum at percentage intervals of 100 (or zero), 91 and 88 of each time cycle, it being understood that the term "time cycle" is herein used to mean the time duration of one revolution of the drum 4 starting with the point of time at which the first of the reference contacts makes contact with the contactor wire 38. During oscillation of the transmitter the home recorder will produce a straight line, but on each interruption of the transmitter this line will be offset to one side as is indicated in the record shown in Figure 9. The space interval between the two broken lines 89 of this record represents one time cycle. On this record at the percentage intervals of 100 (or zero), 91 and 88 there appear the

respective reference marks **90**, **91** and **92** produced by the three fixed contact pins. These reference marks always appear at the same relative positions in each time cycle and serve to identify the time cycle; also, by their fixed relative spacing, they serve as a check on the speed of the contactor drum. In addition to these fixed reference marks, there are respective marks **93**, **94** and **95** produced by the barometer, thermometer and hygrometer resepectively. The percentage intervals between these marks and the zero reference mark **90** will vary with the deflections of the respective measuring instruments and, on proper calibration of the radiosonde, are interpreted into definite measurements of pressure, temperature and humidity.

The deflection range of the barometer may typically be between the percentage points 5 and 70 of each time cycle, with the deflections moving from 70 to 5 for decreasing barometric pressure; the deflection range of the thermometer may typically be between the same percentage points but with the deflections moving from 5 to 70 for decreasing temperatures; and the deflection range of the hygrometer may typically be between percentage points 73 and 85 with the deflections moving from 73 to 85 for decreasing humidity. It will be understood that the zero points of these ranges are established by the zero-adjusting means, hereinbefore described, with which the respective measuring instruments are provided.

The accuracy of a radiosonde of the chronometric type is highly dependent on having the contactor wire **38** of the drum on a true helix; also, the wire should be very narrow—typically .009'' wide or less—so as to limit the time duration of each contact. I find that accurate mounting of such narrow wire on a true helix is very greatly facilitated by providing a peripheral helical groove **96** in the drum which is triangular in cross section and has its leading side—the side first approaching the contact pins as the drum rotates—normal to the surface of the drum. The wire **38** is tapered in cross section to fit the side walls of this groove, and is held wedged into the groove by cementing. The advantage in this construction is that, once the wire is mounted, the drum may be turned down to the desired diameter without causing any deviation in the leading edge of the wire from a true helix.

I have found it to be a characteristic of the hair strands of the hygrometer **3** that they have a substantially zero temperature coefficient of expansion at temperatures in the upper range, typically above 20° C., but that they have a negative coefficient of expansion for decreasing temperature below 20° C. As an indication of the value of this expansion, it may be noted that the hair strands have typically a total expansion in response to decreasing temperature from 20° C. to 0° C. which is equivalent approximately to a 5% change in relative humidity. To compensate the hygrometer for this effect, I provide a bimetal **97** which is clamped in cantilever fashion to the bar **34** just below the supporting spring **25** for the strands. This bimetal is adapted to remain out of contact from the spring **25** for those higher temperatures at which the hygrometer is not sensitive to temperature changes, but is to contact the spring **25** and press against it with varying pressure in the lower temperature range at which the hygrometer is temperature-sensitive. By this expedient, the hygrometer is compensated for its non-linear response to temperature changes.

It will be understood that the embodiment of my invention herein shown and described is illustrative and not necessarily limitative of my invention since the same is subject to changes and modifications without departure from the scope of my invention, which I endeavor to express according to the following claims.

I claim:

1. A temperature-compensated suspension for a hair hygrometer the strands of which tend to vary in length with changes in temperature within a predetermined range and tend to remain substantially fixed in length at temperatures beyond said range, comprising a spring member connected to said strands at one end and holding the strands under tension; and a temperature-sensitive member arranged to be operatively free from said spring member at temperatures outside said predetermined range and to be operatively connected to said spring member to influence the same to varying amount upon changes of temperature within said predetermined range.

2. In an apparatus including a frame: the combination of a hair hygrometer having strands tending to vary in length upon changes in temperature within a predetermined range and to remain substantially fixed in length at temperatures beyond said range; a rigid member spring-hinged to said frame; a spring member secured to said rigid member for holding said strands at one end; a temperature-sensitive member secured to said rigid member and adapted to engage said spring member only at temperatures within said predetermined range to compensate for variations in length of said strands; and means to angularly adjust said rigid member relative to said frame.

3. In an apparatus including a frame and a hair hygrometer the strands of which tend to vary in length upon changes in temperature within a predetermined range and to remain substantially fixed in length at temperatures beyond said range: the combination of a spring member supporting said strands at one end; an indicating member connected to the other end of said strands and actuated by said strands in response to changes in relative humidity; spring means connected to said other ends of the strands for holding the strands under a predetermined tensioning, said spring means having a substantially greater effective compliance than said spring member; and temperature-sensitive means adapted to press against said spring member only at temperatures within said predetermined range to compensate for variations in the length of said strands.

4. In a radiosonde including a frame and an instrument having a pointer for detecting variations in a condition of the atmosphere: the combination of a support member for said instrument movably mounted on said frame; a body of insulating material rotatably mounted on said frame, said body having a surface across which said pointer is moved by said instrument in response to changes in said condition of the atmosphere, said surface having a spiral groove therein; a conductor embedded in said groove and substantially flush with the surface of said body for electrically contacting said pointer, once during each revolution of said body, at varying intervals depending on said atmospheric condition; and means for adjusting said instrument rela-

tive to said frame to predeterminately set said pointer in relation to said conductor.

5. A temperature-compensated hygrometer comprising a humidity-responsive element characterized as being responsive also to temperature variations in a predetermined temperature range and being substantially unresponsive to temperature variations beyond said range; a movable indicating means connected to one end portion of said responsive element; a support for the other end portion of said element; and temperature-responsive means, operatively free from said element at temperatures beyond said range and in operative association with said element at temperatures within said range, for compensating for the response of said element to temperature variations within said range.

6. A rotating electrical contactor for a radiosonde of the chronometric type, comprising a body member of insulating material having a rotating surface across which a pointer is moved in response to a change in atmospheric condition; and a conductor embedded in said body member and exposed at said surface, said conductor having a flat side at its leading edge at right angles to said surface and having a flat side at its trailing edge diverging from said other side towards said surface, and said conductor being substantially flush with said surface.

7. A rotating electrical contactor for a radiosonde of the chronometric type, comprising a body member having a surface across which a pointer is moved in response to variations in atmospheric condition, said surface being provided with a groove of triangular cross section, the leading side of said groove being normal to said surface; and a conductor in said groove having a tapered cross section whereby to fit the sides of the groove, and the exposed portion of said conductor being substantially flush with said surface.

8. In an electrical radiosonde including a frame and an instrument having a pointer for detecting variations in condition of the atmosphere: the combination of means mounting said instrument on said frame; a contactor device including a body of insulating material rotatably mounted on said frame, said body having a surface across which said pointer is moved by said instrument in response to changes in said condition of the atmosphere, said surface having a spiral groove therein; a conductor embedded in said groove and substantially flush with said surface, said conductor having a flat side at its leading edge which is at right angles to said surface, said pointer being adapted to electrically contact said conductor once during each revolution of said body, at varying intervals depending upon said atmospheric condition; and means for adjusting said pointer relative to said contactor device to locate the pointer at a predetermined zero position in relation thereto.

JOHN HORNBOSTEL.

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