April 18, 1944. C. F. WALLACE 2,347,160

RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Fig. 1

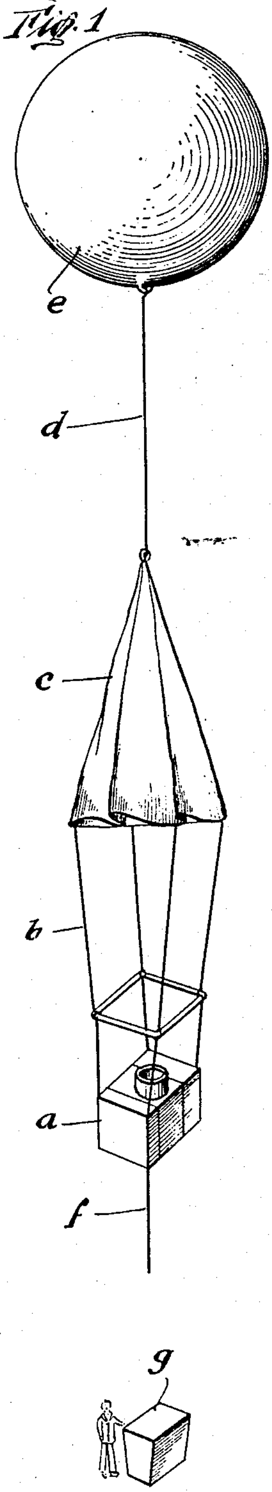


Fig. 3

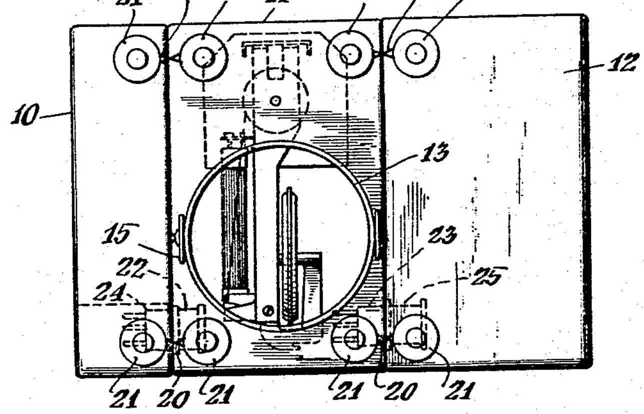


Fig. 2

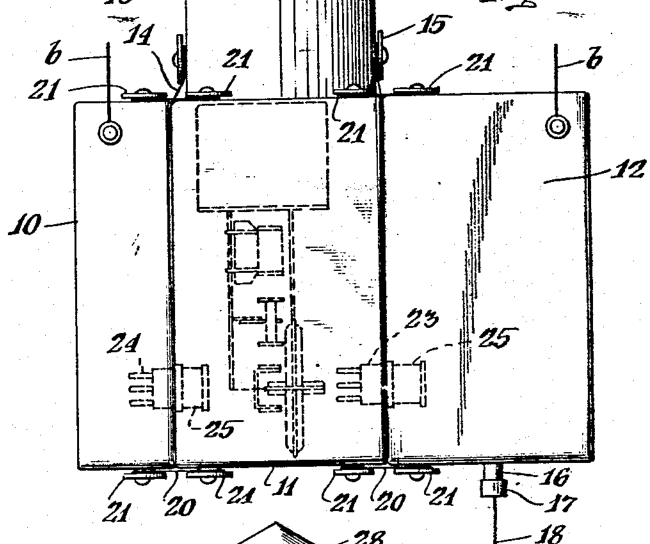
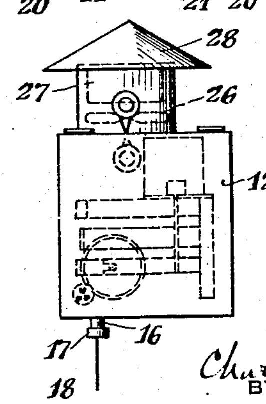


Fig. 4



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RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Fig. 5

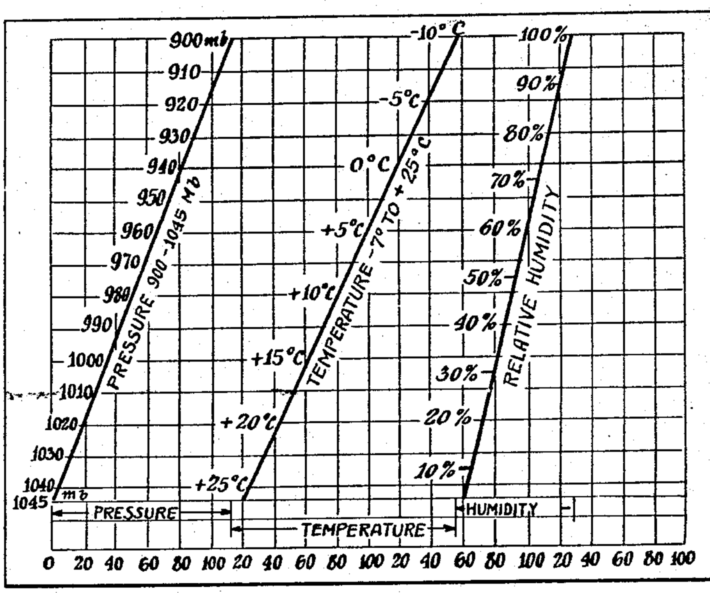
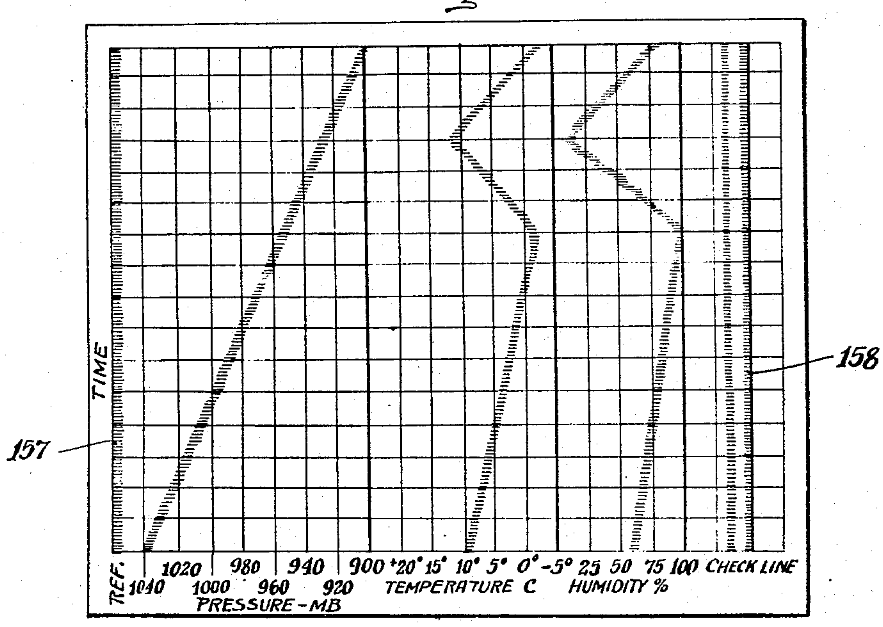


Fig. 6



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RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Fig. 7

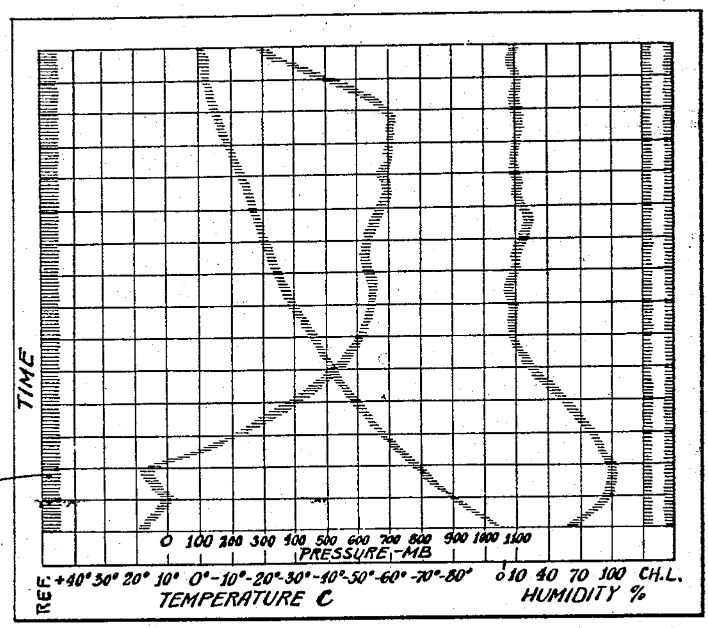
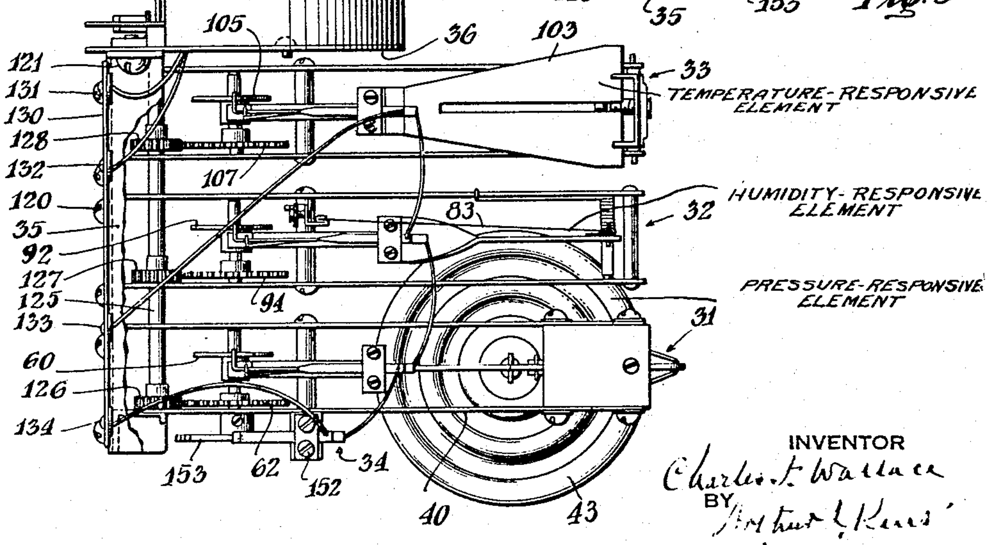


Fig. 8



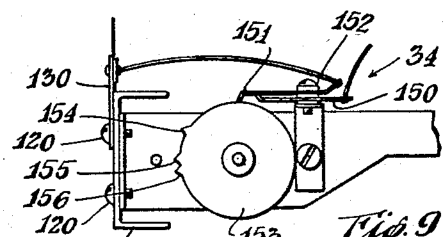


Fig. 9

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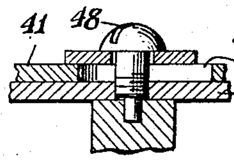


Fig. 10a

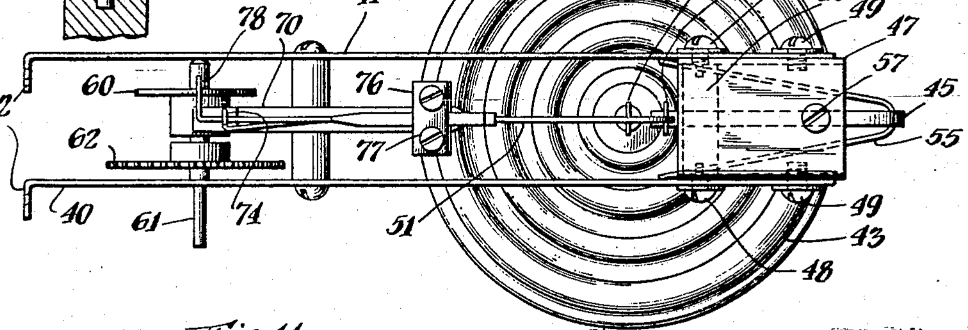


Fig. 10

Fig. 11

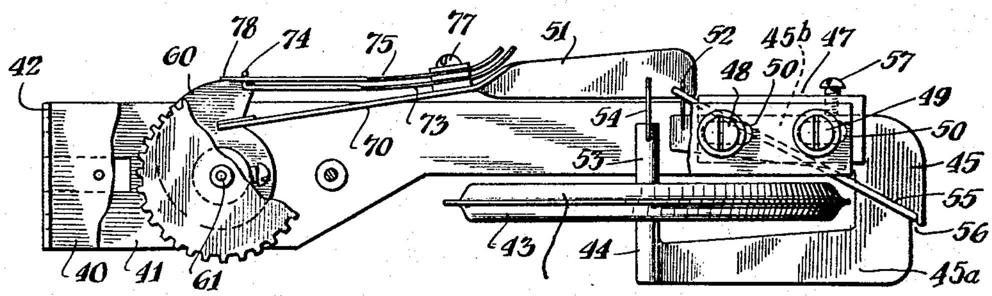


Fig. 12

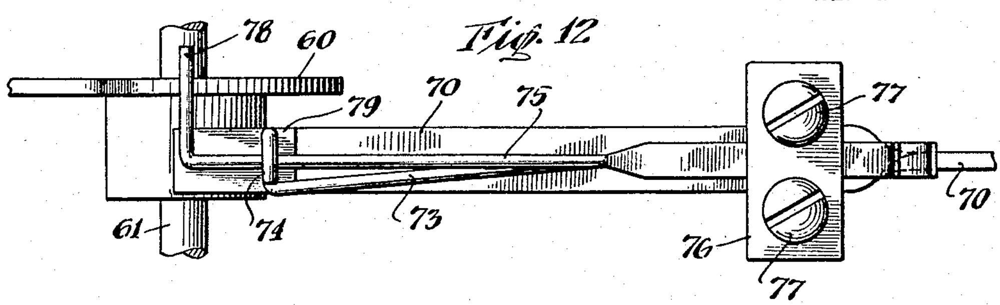
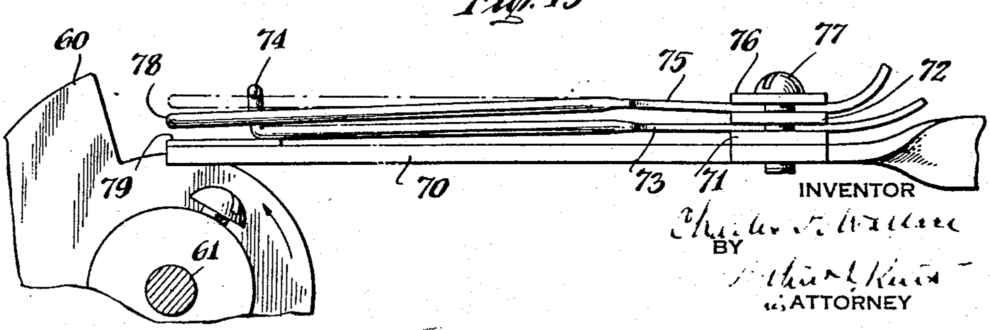


Fig. 13



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April 18, 1944. C. F. WALLACE 2,347,160

RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Fig. 14

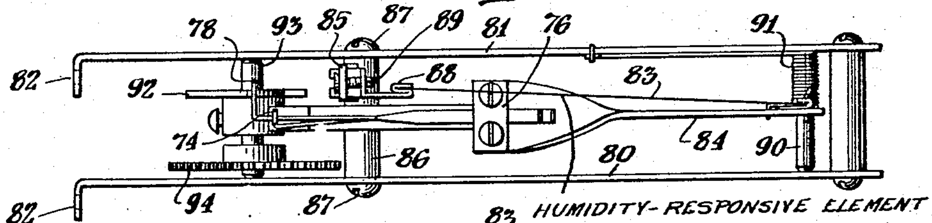


Fig. 15

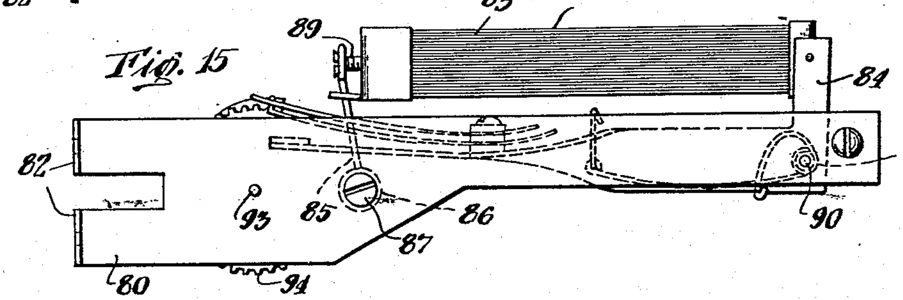


Fig. 16

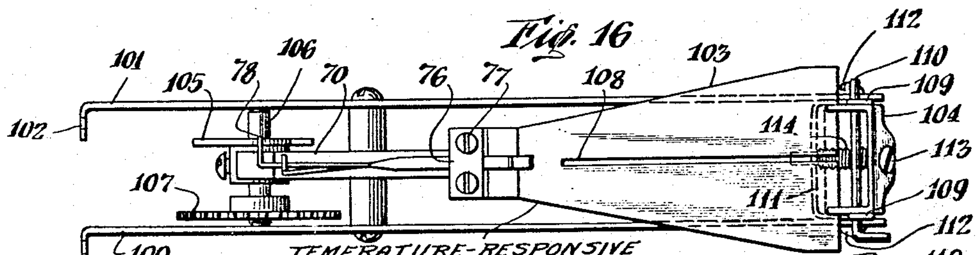


Fig. 17

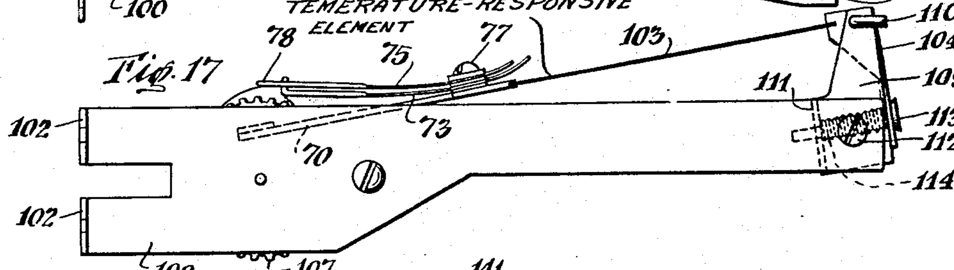


Fig. 18

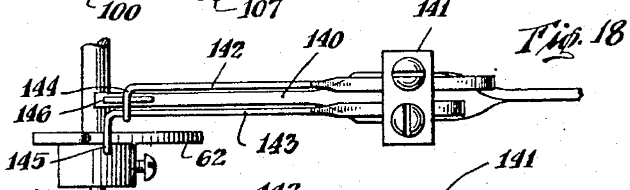
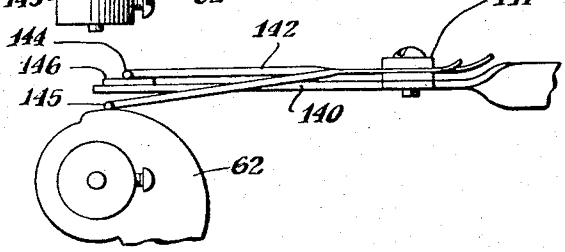


Fig. 19



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RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Fig. 20

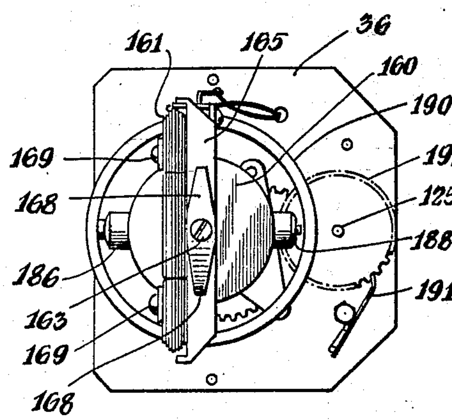


Fig. 21

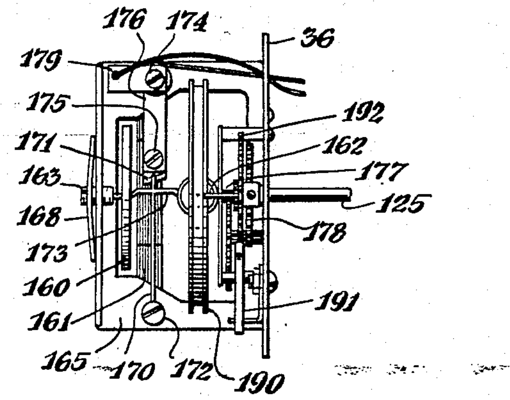


Fig. 22

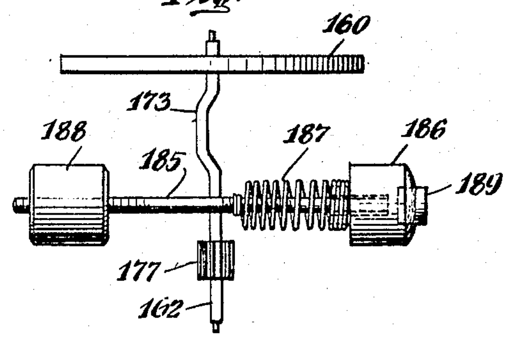


Fig. 23

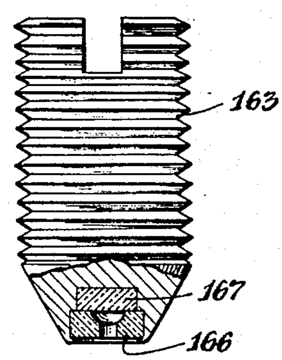


Fig. 25

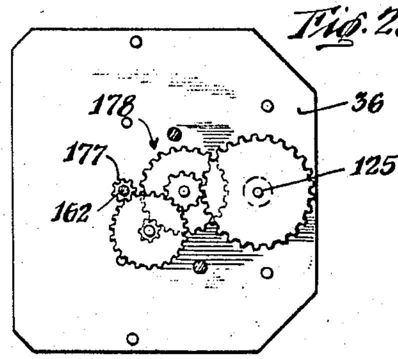


Fig. 24

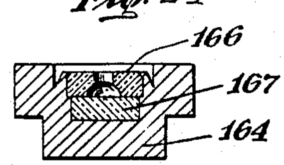
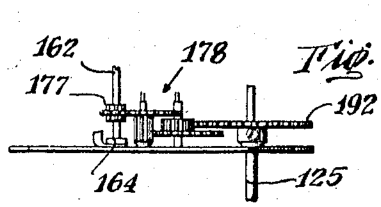


Fig. 26



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RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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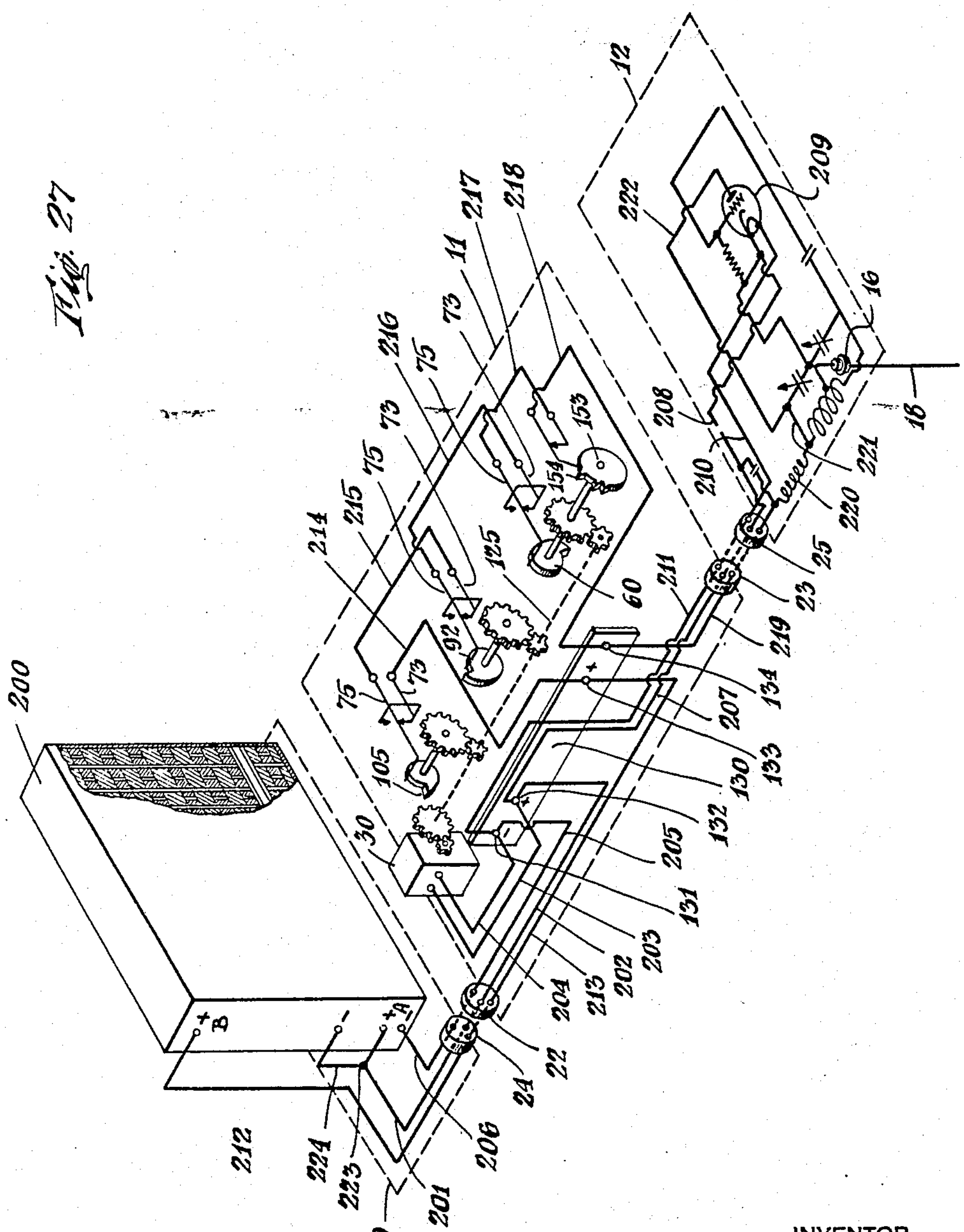
Fig. 27



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RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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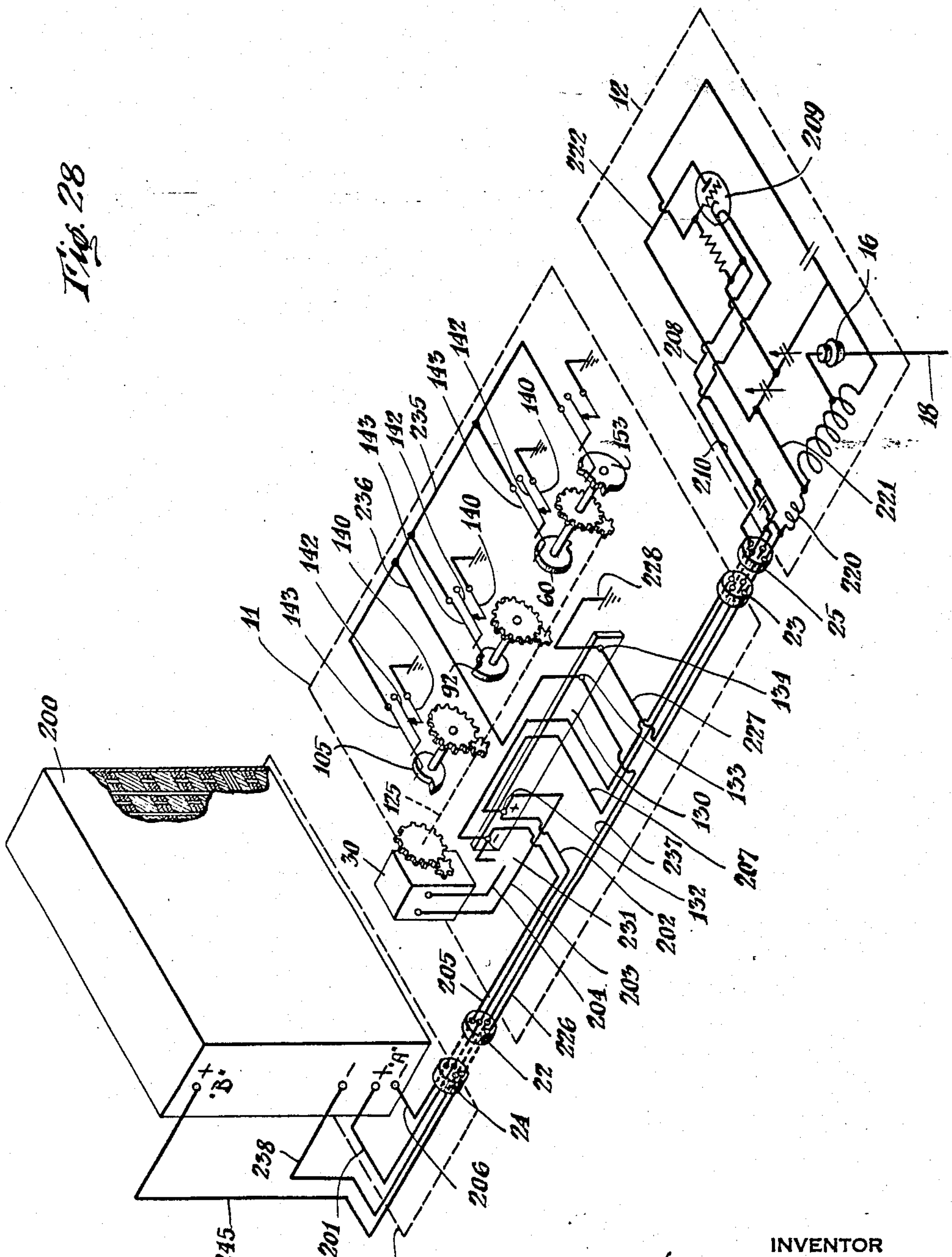
Fig. 28



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Patented Apr. 18, 1944 2,347,160

UNITED STATES PATENT OFFICE

2,347,160

RADIOMETEOROGRAPH TRANSMITTING APPARATUS

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Application April 4, 1940, Serial No. 327,767

29 Claims. (Cl. 177—380)

This invention relates to radiometeorograph transmitting apparatus, or radiosondes, that is, to apparatus for the measurement of meteorological conditions through various levels of the atmosphere and radio transmission of the measurements for recording at a receiving station. More specifically, the invention relates to such apparatus of the time interval type and intended to be carried by a balloon for the determination of the pressure, temperature and humidity values, or conditions, of the atmosphere, and for the wireless transmission of the same to receiving and recording apparatus at a ground station. The invention has been made especially with the idea of providing such an apparatus suitable to be carried by small "sounding" balloons, whether free or captive.

The invention aims generally to provide an improved apparatus of this kind which shall be reliable and accurate in operation, of comparatively light weight, of comparatively low cost and adapted for mass production, easily calibrated, and capable of being readily repaired and adjusted in the field, and having other advantages which will appear from the following description.

Among the special objects of the invention are: to provide a radiometeorograph transmitter having a linear, or straight-line, or other desired calibration; to provide improved pressure, temperature and humidity measuring and transmitting, or circuit-controlling, instruments especially adapted for embodiment in the new radiometeorograph transmitter, but also capable of other uses, and which permit of certain portions of the instrument response being spread or reduced in order to achieve greater accuracy of interpretation of the recorded data; to provide for individual calibration and ready repair or replacement of the several meteorological circuit-controlling instruments; to provide a unit form of assembly of the power supply, the meteorological circuit-controlling devices and motor, and the radio transmitter, which together make up the complete radiometeorograph transmitter, and which are each readily replaceable without disturbing the others; to provide a circuit arrangement and circuit-controlling contact means whereby the radio transmitter is caused to transmit a continuous signal during each cycle of operation with momentary interruptions for indicating the several meteorological conditions; to provide means for signalling the relative speed of the driving motor of the radiometeorological transmitter as compared to that of the recorder at the receiving station; and to provide means for producing an adequate air current past the humidity- and temperature-responsive elements of a radiometeorograph transmitter carried by a captive balloon.

To these ends, the battery or other power source, the motor and meteorological circuit-controlling devices, and the radio transmitter are separately cased, forming separate packages adapted to be readily connected together or disconnected, with provision for establishment of the necessary electrical connections by the act of assembling and connecting the three packages; the meteorological circuit-controlling devices are made as separate individual units adapted to be mounted in assembled relation with the motor on a chassis frame or support, and are of novel construction having important new features and advantages, as will appear from the following description; the meteorological units and the motor are mounted in a manner to obtain the required strength and rigidity with a minimum of weight and to permit ready removal and replacement of individual units and the motor; the radiometeorological transmitter is made to transmit a reference signal at the beginning of each cycle of operations and a motor-speed-indicating, or check, signal at the end of each cycle which may also serve as an identification signal; all as will be hereinafter fully described and specifically pointed out in the claims.

Before proceeding further with a description of the new apparatus, systems and apparatus of the prior art will be briefly discussed.

Radiometeorographs, also known as radiosondes, have been used quite extensively both in this country and abroad during the last five or six years, but until recently they have been more or less of an experimental nature, and designs representative of the ideas of the experimentors in this field are not adaptable to commercial production or to repair or recalibration by average personnel in the field.

The known radiometeorograph transmitters can be roughly classified into two major groups, i. e., those which depend on the change in atmospheric pressure during ascension for the operation of the measuring and transmitting apparatus, and those which employ some form of clockwork for such purpose. Both of the above-mentioned groups can be further sub-divided into two categories, i. e., those which transmit a radio or audio frequency that is variable with the position of the meteorological elements, and those employing a time interval transmitter which utilizes the time between impulses as a measure of the position of the meteorological elements.

In the first-mentioned class, i. e., the type of equipment transmitting variable frequencies, one form of apparatus introduces resistance into the circuit of the audio oscillator which modulates the radio transmitter, the amount of resistance introduced being determined by the position or condition of the barometric, humidity and temperature elements. In another form of apparatus of this general type, the sensitive elements position the plate of a condenser which in turn determines the frequency of the radio carrier wave and, as a result, the variations in radio frequency from a predetermined index value determine the measurements.

Apparatus of the types just described are not particularly accurate due to the numerous variables encountered which tend to influence the frequency of the transmitted signal. To mention but a few, variations in filament and plate battery voltages react on the frequency, temperature changes produce adverse effects; and errors in the frequency determining apparatus at the receiving point often further reduce accuracy.

The use of frequency sensitive radiometeorograph transmitters usually involves extensive and costly ground equipment which can be maintained and serviced only by skilled personnel. Furthermore, the size and weight of this equipment prevents its use as a practical mobile unit.

The motor-operated time interval radiometeorograph transmitters of the prior art employ, so far as I know, some form of clockwork or other non-electric means for operating the telemetric circuit-controlling devices. Due to the great range in temperature encountered, these mechanisms vary greatly in speed, and, furthermore, as some form of escapement is usually necessary, the rotary elements of the apparatus have a step-by-step movement rather than a continuous one, thereby preventing attainment of the high accuracies required for practical purposes.

Clockwork mechanisms are also definitely limited in their power output by space and weight considerations, and, in addition, their power is further reduced and speed variations are accentuated by reason of the fact that the viscosity of lubricants increases at the low temperatures encountered at high altitudes.

In addition to the above stated disadvantages, these time interval type instruments of the prior art also employed various forms of commutators having either radial contact wires extending across a flat rotating disc or spirally wound wires wrapped around a small rotating cylinder, and the contacts positioned by the meteorological elements rubbed against these rotating wires in such a manner as to make new points of contact on successive revolutions of the commutator. In order to reduce friction, the contact pressure was necessarily light and thus not positive in closing, and, in addition, before a contact closure could result it was necessary to break down any film or oxide on the new and not previously used section of the radial or spiral wires, so that electrical contact might not coincide with physical contact, and often no signal or an improperly timed signal was obtained.

In addition to the contacting difficulties explained above, no provision was made in these instruments for correction of the non-linear response of the various meteorological elements or of the circuit-controlling devices operated thereby, and as a result individual calibration curves had to be run for each instrument. Any change or adjustment in the field required a new calibration and the laying out of new calibration curves, and each recorder record had to be corrected and interpreted in terms of the characteristic calibration curves of the particular radiometeorograph transmitter used.

A further great fault with practically all radiometeorograph transmitters of the prior art was the fact that linkages, cord and wire drives, pivoted levers and similar means were used for conveying the movement of the various temperature, pressure and humidity sensitive elements to the telemetering contactors. Due to the small amount of movement available, the sensitivity of the elements to friction, and the fact that play could not be eliminated entirely from such various co-acting means, a serious error between the actual atmospheric condition and the readings transmitted by the radiometeorograph transmitter always existed.

Another very great fault with the type of instrument used prior to the present invention was due to the form of construction employed wherein the several pressure, temperature and humidity-responsive circuit-controlling devices became inherent parts of the complete meteorological transmitter which could be calibrated only as a whole. This prevented interchangeability of individual elements of the complete apparatus in the field, and prevented using methods of calibration most suitable for each particular meteorological circuit-controlling device because of the danger of damaging other such devices not resistant to the same.

As the cost of a precision radiometeorograph transmitter is considerable, a reward is usually offered for its return with the hope that the apparatus can be salvaged and used again for other flights. Due to the form of construction employed prior to the present invention, damage to any one element or even to the radio transmitter or battery often necessitated the complete reconstruction and recalibration of the equipment, whereas with my form of units construction any damaged meteorological circuit-controlling device can be removed in the field and a new calibrated device substituted in a few minutes time, and this same replaceability applies also to the radio transmitter and power supply.

With my linear, or directly proportional, or otherwise predetermined-response circuit-controlling devices, exactly the same range and shape of response curve can be obtained from each one of different radiometeorograph transmitters, and as a result printed recorder charts, calibrated directly in terms of pressure, temperature and humidity can be employed, and data thereon can be used immediately upon receipt without any necessity for the application of any correction factors whatsoever.

A full understanding of the invention can best be given by a detailed description of apparatus embodying the various features of the invention in the form now considered best, and of certain modifications thereof, and such a description will now be given in connection with the accompanying drawings, in which:

Fig. 1 shows a radiometeorograph transmitter according to the invention as it appears attached to a sounding balloon in flight;

Fig. 2 is a side view and Fig. 3 is a plan view of a radiometeorograph transmitter according to the invention intended especially for use with free sounding balloons;

Fig. 4 is an end view of a radiometeorograph transmitter of a form adapted especially for use with captive balloons;

Fig. 5 is a view of a characteristic calibration chart illustrating the linear, or straight line, response obtainable with an apparatus according to the invention;

Fig. 6 shows a record chart having thereon a characteristic record of the type obtained with a low-altitude-captive-balloon-type radiometeorograph transmitter according to the invention;

Fig. 7 is a similar view showing a characteristic record of the type obtained with a high-altitude free-flight radiometeorograph transmitter according to the invention;

Fig. 8 is a side view of the assembled meteorological units and motor;

Fig. 9 is an end view showing the indexing contacts and cam disc which appear at the right of Fig. 25;

Fig. 10 is a side view, and Fig. 11 a plan view, of the telemetric barometric circuit-controlling unit of the apparatus;

Fig. 10a is an enlarged detail sectional view of a part shown in Figs. 10 and 11;

Fig. 12 is a side view, and Fig. 13 a plan view on a larger scale showing the contact make-and-break members, or contact assembly, and operating cam which form part of the barometric unit and of each of the other meteorological units of the apparatus;

Figs. 14 and 15 are, respectively, side and plan views of the telemetric hygrometric circuit-controlling unit of the apparatus;

Figs. 16 and 17 are, respectively, side and plan views of the telemetric temperature-controlled circuit-controlling unit of the apparatus;

Figs. 18 and 19 are, respectively, side and plan views of a contact assembly for use in the meteorological units of the apparatus when the signals are to be transmitted as short radio impulses rather than as interruptions in a continuous signal;

Fig. 20 is a view of an electric motor suitable for use as part of an apparatus according to the invention, the view being taken looking toward the plate on which the motor parts are mounted;

Fig. 21 is an edge view of the motor looking from the right of Fig. 20;

Fig. 22 is a detail view on a somewhat larger scale showing the motor shaft and governor rod carried thereby;

Fig. 23 is a further enlarged detail view partly in section of the bearing member for one end of the motor shaft;

Fig. 24 is a sectional view on the scale of Fig. 23 of the bearing member for the other end of the motor shaft;

Figs. 25 and 26 are, respectively, side and edge views showing the reduction gears of the motor;

Fig. 27 is a wiring diagram of a complete apparatus according to the invention for transmitting signals as momentary interruptions in a continuous signal; and

Fig. 28 is a similar view illustrating a modified form of the apparatus for transmitting the signals by short radio impulses and employing the contacting devices of Figs. 18 and 19.

Use of the new apparatus and its general appearance in flight when carried by a free balloon are illustrated by Fig. 1, which shows the radiometeorograph transmitter *a* suspended by cords *b* from a small parachute *c*, which in turn is suspended by a cord *d* from a small free balloon *e* inflated to a predetermined degree with a light gas such as helium or hydrogen, an antenna *f* extending downward from the radio transmitter casing. A receiving apparatus *g* and operator at the ground station are also indicated.

The new radiometeorograph transmitter comprises three principal divisions or parts housed in three separate containers **10**, **11** and **12**, batteries forming the power source being in container **10**, the meteorological transmitter comprising the driving motor and meteorological circuit-controlling devices, or telemetering transmitters, and indexing circuit-controlling device in container **11**, and the radio transmitter in container **12**, the three containers with their enclosed apparatus parts being assembled and secured together as shown in Figs. 2 and 3 to form the complete radiometeorograph transmitter. The apparatus parts within the containers are somewhat diagrammatically indicated in Figs. 2 and 3. This unit type of construction has the advantage that in the event of damage to any unit, the damaged unit may easily and quickly be disconnected and a new like unit substituted. Also, the radio transmitter can be rapidly interchanged with one designed for operation on a widely different frequency or having some other different characteristic, and other types of power supplies can be readily attached, for instance, the engine generator apparatus covered by my copending application Serial No. 317,635, filed February 7, 1940, when greater power or length of operating period is desired.

Each of the containers **10**, **11** and **12** is made of corrugated paper, balsa wood, or other suitable light-weight heat-insulating material, and they are most desirably coated on the outside with a glossy white waterproof paint or else made of a suitable light-reflecting material, so as to limit the absorption of heat from the sun's rays. Metallic coatings such as aluminum paint or foil can also be used, but in such case the container **12**, which houses the radio transmitter, must be of such size and shape as to prevent any undesirable reaction due to the presence of this metallic coating adjacent to parts of the radio transmitting equipment carrying radio frequency currents. The central container **11** has ventilating openings in its top and bottom walls to permit free passage of air through the casing chamber so that the contained humidity- and temperature-sensitive elements are continuously laved by an air current flowing through the chamber while the instrument is ascending. The initial rate of ascension is usually in the neighborhood of 600 feet per minute. In order to prevent erroneous readings due to impingement of sun's rays on the meteorological elements, a sun shield is provided formed by a tube **13** the lower slightly reduced end of which extends through the opening in the top wall of the container and which is fastened in place by suitable means such as cords **14** and wrap-around tabs **15**. A tube of sufficient length serves as a suitable solar shield except when the sun is directly overhead, and avoids interference with the desired air flow through the chamber; but additional sun-shielding means may be provided as may be required.

A small antenna insulator **16** of suitable radio frequency insulating material, such as that commercially known as "Isolantite," is set into the bottom wall of the container **12** which houses the radio transmitter, and carries a terminal clamp **17** for securing the end of an antenna wire **18**. The antenna **18** is preferably made of copperclad or copper plated steel wire of small diameter so that it will not become permanently distorted if it should hit some object when the balloon is launched. For the apparatus shown, it should be a half-wave antenna, but any suitable type of antenna may be used depending on the type of radio transmitter and method of antenna coupling used.

The three containers are secured together, with container 10 on one side and container 12 on the opposite side of container 11, by connecting means adapted to permit of ready separation of the containers and ready connection thereof in assembled relation. Most desirably, cords 20 and wrap-around tabs 21 are used for this purpose, the tabs being located preferably near the edges of the top and bottom walls of the containers as appears in Figs. 2 and 3. The central container 11 has set in its opposite side walls against which containers 10 and 12 are assembled a light-weight connecting plug 22 in one wall and a light-weight socket 23 in the other, and the inner side wall of container 10 is provided with a complementary socket 24 for coacting with the plug 22 and the inner side wall of container 12 has a plug 25 for coacting with the socket 23, to make the necessary electrical connections between the apparatus parts housed in the three containers.

The bridle cords b are fastened to reinforced parts of containers 10 and 12 so that the complete radio-meteorograph transmitter is thereby suspended and held in the proper position in flight. Instead of the simple arrangement shown, it is preferable under certain conditions to have a swivel connection between the transmitter and the parachute in the customary way so that any tendency of air currents to rotate the transmitter will not result in snarling the support cords whereby proper opening of the parachute might be prevented.

While the mere provision of openings for permitting air flow through the central container 11 is all that is necessary for obtaining a continuous air current through the container chamber in the relatively small radiometeorograph transmitters intended to be attached to free balloons, it is desirable to provide means for inducing the desired air flow in transmitters intended to be carried by captive balloons in order to assure adequate ventilation of the temperature and humidity elements. For creating the desired air current through the container which houses such elements in transmitters intended to be carried by captive balloons, an arrangement such as shown in Fig. 4 is most desirably provided. As shown by dotted lines in this figure, a fan 26 is provided in the air tube 13 driven by a small motor 27 receiving its current from the battery in the casing 10 and serves to create an upward draft of air through the metering chamber and out through the air spaces under the edge of a conical cap 28 which also provides an effective sun shield at all times and prevents the entrance of rain or snow.

In radiometeorograph transmitters according to the invention intended for use with captive balloons, it is desirable to use temperature and pressure elements of somewhat larger size so that a relatively large movement of the telemetering contacts is obtained over the more limited pressure and temperature ranges encountered. It is also often desirable in the instruments for captive balloon use to employ larger radio transmitting apparatus and larger power supplies so that much longer periods of operation may be obtained than with the high altitude devices made for free balloons which usually are in flight for not more than about ninety minutes at a time. Even though the larger radio transmitters, and especially the larger batteries or other power source, means greater weight, this is permissible because of the greater lifting power of the captive balloons used for this type of service.

The power source housed in container 10 for supplying current for the radio transmitter and the driving motor may consist of a 6-volt filament, or A, battery and a 90-volt plate, or B battery. Radiometeorograph transmitters for free flight balloons usually have a comparatively low powered radio transmitter, and for such transmitters batteries of the primary, or dry cell, type are suitable. When higher powered radio transmitters are used, or greater duration of flight required, and when the apparatus is of the continuous signal type, miniature "A" and "B" batteries of the secondary, or storage cell, type may be used, and batteries of this type are shown in Figs. 27 and 28.

The apparatus parts housed in container 11 are shown in Fig. 8, these parts being the motor enclosed within a protecting housing 30 of aluminum or other suitable light material, the pressure-responsive telemetering transmitter unit 31, the humidity-responsive telemetering transmitter unit 32, the temperature-responsive telemetering transmitter unit 33, and an indexing circuit-controlling device 34. The pressure, humidity and temperature units are mounted side by side in a channel-shaped chassis or support bracket 35 and are separately detachable therefrom. The motor parts, including the housing 30, are carried by a plate 36 which is detachably secured to the end of the chassis 35. The parts of the indexing circuit-controlling device 34 are mounted on the frame of the pressure unit. The pressure, humidity and temperature units are each entirely self-contained and complete, having a driving connection to a common motor-driven shaft and electrical connections from their contact members to the radio transmitter and to the battery, and, being separately and detachably mounted on the chassis, each unit may be taken away from the others for calibration and any damaged unit may readily be removed and replaced by a like unit.

The pressure unit 31 is shown in side and plan view on an enlarged scale by Figs. 10 and 11. All the operating parts of the unit are carried by a frame having two parallel spaced side plates 40 and 41 each of which has at one end a flange 42 with tapped screw holes for attachment to the chassis 35. The unit comprises a pressure element, or capsule, 43, of more or less conventional construction consisting of two somewhat dished corrugated diaphragms of metal of high elastic limit joined together at their peripheries to form a chamber from which air is evacuated. Under certain conditions, it is considered best to evacuate this chamber to as high a degree as possible, but under other conditions, it is desirable that a small residuum of air be left in the chamber for temperature compensating purposes. The pressure capsule is rigidly secured by means of a stud 44 extending from one side of the capsule to one arm 45a of a U-shaped support member 45 the two arms of which extend on either side of the capsule and the other arm 45b of which carries a shaft 46 which extends between the flanges of a plate 47 set between the side plates 40 and 41, the shaft being pivoted on the ends of clamping screws 48 screwed into threaded openings in the flanges of plate 47, as shown in Fig. 10*a*. The flanged plate 47 is adjustable longitudinally between the side plates 40 and 41 to which it is normally clamped by the screws 48 and screws 49, these screws extending through short slots 50 in the side plates to permit such longitudinal adjustment of the flanged plate 47 when the clamping screws are loosened. A transmitter arm 51 which carries at its outer end the circuit-controlling contact assembly is pivotally connected at its inner or fulcrum end to the arm 45*b* of the U-shaped member 45 by a transversely-extending thin plate or leaf of spring metal 52, which may be beryllium-copper, Phosphor-bronze, or the like, the opposite edges of this pivot plate being set in transverse slots in the end of the arm of the U-shaped member and in the end of the transmitter arm and being secured therein by solder. The transmitter arm is also similarly connected to a stud 53 extending from the opposite side of the capsule 43 from that from which the stud 44 extends by a similar thin plate or leaf spring metal 54 extending into and soldered in transverse slots in said stud and in the transmitter arm.

A spring 55 formed of a U-shaped spring wire having its bight engaged in a notch 56 in the U-shaped member 45 and its two legs extending over the shaft 46 and into engagement with the inner edge of plate 47 yieldably urges the member 45 in an anti-clockwise direction, as viewed in Fig. 11, which movement of the U-shaped member is limited by an adjusting screw 57. By turning the screw 57 in one direction, the U-shaped member is permitted to swing in anticlockwise direction under tension of its spring 55, and when the screw is rotated in the opposite direction, a downward movement of the right hand end of the U-shaped member as viewed in Fig. 11 results.

A cam 60 of Bakelite or other non-conducting wear-resistant material mounted fast on a shaft 61 journalled in the side plates 40 and 41 and driven by means of a gear 62 operates the contact assembly carried by the transmitter arm 51 to open momentarily a normally closed circuit to the radio transmitter at a time during each revolution of shaft 61 dependent on the position of the transmitter arm 51 as determined by the condition of the pressure capsule 43 in response to the atmospheric pressure.

The circuit-controlling contact members, constituting the contact assembly, carried by the transmitter arm 51 of the pressure unit, are shown on a larger scale by Figs. 12 and 13. Each of the other two meteorological units has a like contact assembly. The transmitter arm 51 of the pressure unit is extended to form, and the corresponding member of the other units, carries, or is extended to form, a support bar or strip 70, and on this support bar at a suitable distance from its outer end is mounted a plate 71 of insulating material, such as Bakelite, and between this plate and a similar plate 72 is secured the flattened end of a spring contact rod or wire 73, preferably of silver or other rare metal, the free end of which is bent transversely and then over to form a U, as indicated at 74, thus providing in effect two spaced contact terminals. Another similar contact rod or wire 75 has its flattened end clamped between the insulating plate 72 and a third plate 76 of insulating material, the three plates being clamped together by means of screws 77, the contact rods thus being adjustable longitudinally on loosening the screws 77. The free end of this second contact rod 75 extends through the U-form end of the rod 73 and beyond this U-end is bent at right angles to form a cam-engaging end 78.

The two contact rods 73 and 75 are tensioned so that when not engaged by the cam 60 the end of rod 73 rests on a piece of insulating material 79 secured to the upper side of the support bar 70 and the end of rod 75 rests on the lower arm of the U-end of rod 73 as viewed in Fig. 13. When the cam 60 on its revolution makes contact with the cam-engaging end 78 of the contact rod 75, the rod 75 is raised out of engagement with the lower arm of the U-form end of the rod 73, thus opening the circuit at this point, and then, as the revolution of the cam continues, the rod 75 is raised further into engagement with the upper arm of the U-form end of rod 73, thus re-establishing contact between the two contact rods, and thereafter rods 73 and 75 are moved together until the high point of the cam passes beyond the end 78 of rod 75, whereupon the rods return to their position of rest on the end of the support bar. Contact between the two rods 73 and 75 is thus interrupted for a very short period, say, a second or less, during each revolution of the operating cam 60, while the rod 75 is moved by the cam from the lower arm to the upper arm of the U-form end of rod 73. Therefore, the transmitter circuit will be interrupted at some time during the rotation of the cam, and the time in each rotation of the cam, that is, the position in time in each successive cycle of the operation of the device, will depend on the angular motion imparted to the support bar 70 by the pressure, humidity or temperature element, as the case may be.

Going back, now, to the pressure unit shown in Figs. 10 and 11, if the movement imparted to the transmitter arm 51, and as a result to the contact assembly carried thereby, is non-linear, that is, not proportional to changes in the atmospheric pressure as measured by the pressure capsule 43, the contour of the cam 60 of this unit can be so shaped as to produce time interval increments that are linear or directly proportional to changes of atmospheric pressure. Also, the contour of the operating cam 60 can be shaped to produce non-uniform time interval increments, thereby permitting certain portions of the pressure range to be spread out on the recorder chart in order to permit their more accurate study on the chart. For example, with a constant rate of ascent the change in pressure near the ground will be much more rapid than at high altitudes. A pressure change of 50 millimeters of mercury at sea level represents a change in altitude approximating 1870 feet; whereas a change of 50 millimeters at an altitude where the pressure is 200 millimeters of mercury represents a change in altitude of over 6000 feet; so that it would sometimes be of advantage to deform the periphery of the cam 60 to cause a given range of the lower pressures to spread over a greater portion of the total cam revolution than a similar range at the higher pressures.

By loosening the clamping screws 48 and 49 and adjusting the flanged plate 47 longitudinally, thereby adjusting the transmitter arm 51 and the contact assembly carried thereby longitudinally with relation to the cam 62, and making a compensating longitudinal adjustment of the contact rod 75 to keep its bent contact end 78 in proper position with relation to the cam, the magnitude of movement imparted to the transmitter arm and contact assembly by the barometric capsule for a given pressure change may be adjustably varied, thereby adjustably varying the spread on the recorder chart of the data marking indicating such pressure change. By such adjustment, therefore, variations in the expansion and contraction of the barometric capsule resulting from difference in the materials or construction of the capsule can be compensated for, and the movement of the transmitter arm can be maintained within any desired predetermined range in all instruments.

Angular adjustment of the transmitter arm by means of the adjusting screw 57 determines the point on the cam, and, therefore, the time in the cycle at which the contact assembly is operated by the cam for any condition of the barometric capsule, that is, for any atmospheric pressure. This adjustment, therefore, determines the time in each cycle of operations at which the pressure signals are transmitted, and therefore determines the position of the range of pressure markings on the chart of the recording instrument.

Therefore, by longitudinal adjustment of the transmitter arm 51 and compensating adjustment of the contact rod 75, the horizontal spread of the data markings on the recorder chart may be adjusted to agree with the spacing of the printed pressure lines of the chart, and by the angular adjustment of the transmitter arm, the exact location on the chart of the data markings may be adjusted to the printed chart markings. The instrument may thus be readily calibrated so that its transmissions will result in a record which may be read directly without resort to any correction factors whatever. By providing cams having predetermined effective peripheral lengths, the pressure recordings, (and the same is true for temperature and humidity recordings as will appear), may be located in definite zones on the recorder chart without overlap, as shown, for example, by Fig. 6, which indicates a typical record as made by a low altitude instrument, or, as a further example, the temperature and pressure readings may be spread over a major portion of the recorder chart and the humidity readings confined to a minor portion as illustrated by the typical high altitude record of Fig. 7. The straight line calibration curves obtainable with the new pressure, humidity and temperature units are illustrated by Fig. 5.

The humidity-responsive telemetering transmitter unit 32 of the apparatus illustrated is shown in side and bottom plan views in Figs. 14 and 15. In this unit the operating parts, as in the pressure unit, are carried by a frame having two side plates 80 and 81 which have flanges 82 at one end with screw holes for attachment to the chassis 35. The humidity-sensitive element 83 is of the well known hair type consisting of a multiplicity of hairs extending in close arrangement side by side and held at the ends by metal clamps. This hair element is pivotally connected at one end to one arm of an L-shaped support member 84 and at its other end to the end of a rod 85. The rod 85 extends from and is rigidly secured to a cross-member 86, which extends between the side plates 80 and 81 and is secured thereto and clamped against turning by clamping screws 87. The rod 85 is thus adjustable for varying the initial position of the hygrometer element by loosening the screws 87 and then tightening them when a desired adjustment has been made. The connection of the upper end of the rod 85 to the metal clamp 88 of the hygrometer element is by means of an adjusting screw 89 which extends through an eye in the end of the rod and screws into the flanged end of a plate extending from the clamp 88. By means of this screw, very accurate adjustment may be made of the position of the hair element for the purpose of adjusting the contact assembly of this unit with relation to its operating cam in a manner similar to that resulting from adjustment of the screw 57 of the pressure unit.

The L-shaped member 84 is carried by a shaft 90, which is journalled in the side plates 80 and 81, and a coiled spring 91, which has its inner end hooked over the lower arm of the L-shaped member as viewed in Fig. 15 and its outer end hooked over the upper side of the side plate 81, constantly urges the L-shaped member to rotate in a clockwise direction as viewed in Fig. 15 and thereby to maintain the hairs of the hygrometer element under constant tension. The lower or longitudinally extending arm of the L-shaped member 84 carries at its outer end a contact assembly similar to that of the pressure unit and as shown by Figs. 12 and 13 and which is operated by an insulated cam 92 on a shaft 93 journaled in the side plates 80 and 81 and driven through a gear 94. As the contact assembly is the same as that of the pressure unit and as shown in Figs. 12 and 13 and is operated in the same manner by its cam to open the circuit momentarily at a time during each revolution of the cam determined by the hygrometer unit, it need not be further described. It will be understood that the L-shaped member 84 will be given a slight angular movement as the hygrometer elements expands or contracts with changes in the amount of moisture present in the atmosphere, this movement of the member 84 causing the cam-engaging end 78 of the contact rod 75 supported by the bar 70 to move toward or from the cam 92.

The temperature-responsive unit 33 of the apparatus is shown in Figs. 16 and 17. As before, the operative parts of this unit are carried by a frame having two spaced side plates 100 and 101 which have flanges 102 with screw holes therein for attachment of the unit to the chassis 35. The temperature-responsive element 103 of this unit as shown is a thin bi-metal plate or strip rigidly connected at one end to a hinged flanged, or U-shaped, member 104, the edge of the bi-metal strip being entered into slots in the two flanges of the member 104 and soldered therein. By connecting the bi-metal strip to its supporting member in this way, there is a minimum amount of thermal contact between the two. This is desirable for obtaining rapid response to temperature changes, as there is little, if any, effect on the temperature-sensitive element by heat stored in the somewhat more massive portions of the apparatus. The opposite end of the bi-metallic strip 103 carries the support bar 70 and other parts of the contact assembly, which, here again, is the same as in the pressure and humidity units and as shown by Figs. 12 and 13, and the contact assembly is operated by an insulated cam 105 fast on a shaft 106 journaled in the side plates 100 and 101 and driven by a gear 107. Most desirably, the bi-metallic plate or strip 103 has a slot 108 extending from its supported or heel end and for a good part of its length for the purpose of equalizing any strains produced by attachment to the hinged member 104, thereby preventing any buckling effects which might otherwise cause an error in the temperature determinations.

The U-shaped member 104 is pivotally mounted between two plates 109 on a pivot pin 110, which plates are connected at their lower inner edges by a cross plate 111 forming a support member which is pivotally mounted between the side plates 100 and 101 by means of pivoting and clamping screws 112. By loosening the screws 112 the plates 109 may be adjusted angularly, thus providing for substantially longitudinal adjustment of the temperature-responsive element 103 with relation to the cam 105. By such adjustment of the element and by a compensating adjustment of the cam-engaging contact member of the contact assembly to keep it in proper position with relation to the cam, the magnitude of movement imparted to the contact assembly by the temperature-responsive element for a given temperature change may be adjustably varied. An adjusting screw 113 passes through a clearance hole in the lower part of hinged member 104 and through a compression spring 114 and threads into the cross plate 111. By adjusting this screw, the angular position of the hinged member 104 and of the temperature-responsive element and the contact assembly carried thereby can be varied in the manner and for the same purpose as described in connection with the angular adjustment of the member 45 of the pressure unit as shown in Figs. 10 and 11.

Referring now again to Figs. 8 and 9, the channel shaped chassis 35 provides a rigid support for the three meteorological units and the motor arranged in line, the meteorological units being secured to the chassis by screws 120 extending through the bottom wall of the chassis into the tapped holes in the end flanges of the side plates of the units, and the motor bed plate 36 being secured to outturned ends of the side flanges of the chassis by screws 121 of which one shows in Fig. 8.

A low speed drive shaft 125, driven by the motor in the housing 30, extends longitudinally of the chassis 35, being journaled at one end in the motor bed plate 36 and at the other end in the side plate 40 of pressure unit 31. The drive shaft carries three pinions 126, 127 and 128 which mesh respectively with the gears 62, 94 and 107 of the units 31, 32 and 33. These pinions are secured to shaft 125 by means of spring collets or other adjustable means which permits of their being twined on the shaft relatively to each other so that the operating cams 60, 92 and 105 of the units 31, 32 and 33 may be accurately adjusted to set them in the desired relative angular position and yet which will not yield or slip when shaft 125 is driving the cams. The speed of shaft 125 and the relative size of pinions 126, 127 and 128 and gears 62, 94 and 105 may, for example, be such that the operating cams will be driven to make a complete rotation in 15 seconds or in 30 seconds, but may, of course, be such as to give any desired rate of rotation to the cams.

A terminal strip 130 of insulating material is secured to the bottom of chassis 35 and carries four terminal lugs 131, 132, 133 and 134. The terminal lugs 131 and 132 are used for connecting the motor to the battery or other power source, and the terminal lugs 133 and 134 serve for connecting the contact assemblies of the meteorological units into the circuit of the radio transmitter. When the apparatus is such that the radio transmitter is caused to transmit a continuous signal in which momentary interruptions are caused during each cycle of operation by the indexing device and by the several meteorological units, the circuit-controlling contact assemblies of the meteorological units are of the type shown in Figs. 10 to 17, and are connected in series between the terminal lugs 133 and 134. Each meteorological unit then operates, as above described, to open the circuit momentarily during each cycle of operations at a point determined by the meteorological condition measured by the unit. This is also a very short opening of the circuit when the cam-engaging end 78 of each contact rod 75 drops off from the high point of its operating cam, but these circuit openings are too short to be effective to cause a record-producing signal to be transmitted.

Because of the unit form of construction, the meteorological instruments can be individually calibrated before assembly, under conditions ideal for each one, and then after calibration be mounted on the chassis 35 and secured as stated.

If the apparatus is of the normally open-circuit type by which intermittent radio impulses determined by the meteorological conditions are transmitted, the contact assemblies of the meteorological units of the apparatus are connected in parallel instead of in series, the terminal 133 being connected to one contact member of the contact assembly of each of the meteorological units and the other contact member of each unit being grounded to the chassis, the terminal lug 134, from which connection is made to the radio transmitter, as shown in Fig. 28, being also grounded to the chassis. The contact assemblies of the meteorological units of an open circuit apparatus may be of the kind shown by Figs. 18 and 19, such contact assemblies being substituted in each of the meteorological units in place of the contact assembly shown by Figs. 12 and 13 and in Figs. 10 and 11 and 14 to 17.

Referring now to Figs. 18 and 19, the contact members are carried by a support bar 140 similar to the support bar 70 of Figs. 12 and 13, and which like the support bar 70 either is an extension of or is carried by the transmitter arm or corresponding part of the meteorological unit, being shown in Figs. 18 and 19 as an extension of the transmitter arm 51 of the pressure unit. This support bar 140 has mounted thereon two plates 141 of insulating material between which are clamped two spring contact rods 142 and 143 spaced and therefore insulated from each other. The contact rod 142 has a bent-over end 144 which extends over the end of support bar 140 and over contact rod 143. Contact rod 143 extends slightly beyond the bent-over end 144 of rod 142 and has a bent-over end 145 which extends in position to be engaged by the periphery of the operating cam, marked 62 in these figures, assuming it to be the cam of the pressure unit. A small contact piece of rare metal 146 is soldered to the free end of the support bar 140 in position to be engaged by the end 144 of the contact rod 142. From this contact piece grounding connection is made through the support bar and through other parts of the unit to the chassis 35, and thus to terminal lug 134. Contact rod 143 is connected to terminal lug 133. Contact rod 142 is tensioned to rest normally on the contact piece 146, and contact rod 143 is tensioned toward the cam to be normally out of contact with the end 144 of rod 142, so that until contact rod 143 is lifted sufficiently by the cam to come into engagement with the end 144 of rod 142, the circuit is open at this point.

When, however, contact rod 143, as it is moved by its operating cam, comes into engagement with the end 144 of rod 142 which is resting on contact piece 146, circuit is momentarily closed between rod 143 and support bar 140. This closing of the circuit will be only momentary since by the continued rotation of the cam the rod 143 will be caused to move rod end 144 out of engagement with the contact piece 146, thus opening the circuit, the time duration of this momentary closing of the circuit being determined by the yielding of the spring contact rods and the lift and speed of rotation of the cam. Thus, during each rotation of its operating cam, each of the meteorological units, having a contact assembly such as shown by Figs. 18 and 19, will cause the radio transmitter to be momentarily energized to transmit an impulse at a time in the cycle determined by the setting of its cam and the meteorological condition to which the unit is responsive.

By having the contact 146 insulated from the support bar 140, as by mounting it on a plate of insulating material such as the plate 79 of Fig. 13, a completely insulated keying device may be obtained. The connections to the same would then be made, one to contact 146 and the other to contact rod 143, thus doing away with the grounding of 146 to the chassis.

Referring again to Figs. 8 and 9, the indexing circuit-controlling device 34 comprises a contact assembly formed by a contact rod 150 and a spring contact rod 151, both held and insulated from each other by a clamping pile 152 carried by a bracket attached to the side plate 40 of the pressure unit 31, and a cam disc 153 mounted fast on an extended end of the cam shaft 61 of the pressure unit. Cam disc 153 has a short peripheral propjection 154 and has, spaced a short distance from this projection in the direction of its rotation, two closely spaced short peripheral projections 155 and 156. Contact rod 151 is tensioned toward rod 150 and is normally in circuit-closing engagement with the end of rod 150, and its end beyond the end of rod 150 extends toward the periphery of the cam disc in position to be engaged and moved by the cam projections 154, 155 and 156 to open the circuit. The two contact rods, as shown in Fig. 8, are connected in series with the contact assemblies of the meteorological units between the terminal lugs 133 and 134.

The cam projections are so positioned on the periphery of the cam disc, and the disc is so positioned angularly with relation to the angular positions of the cams 60, 92 and 105 of the meteorological units, that the projection 154 operates the contact rod 151 to open the circuit momentarily at the beginning of each cycle of operations and the dual projections 155 and 156 cause two closely spaced momentary openings of the circuit at the end of each cycle after the three meteorological units have made their circuit interruptions. Unlike the interruptions made by the meteorological units, the circuit interruptions caused by the projections on cam disc 153 always occur at predetermined points in the cycle, and, therefore, if the speed of the motor is constant, the time interval between the circuit opening movements of contact rod 151 caused first by projection 154 and then by projections 155 and 156 will be constant, and the distance between the record markings caused by these circuit openings will not vary in successive cycles if the speed of the recorder motor is also constant.

In an apparatus designed to produce by signal transmission to a receiving station such as hereinafter referred to a record such as shown by Fig. 6, the relative angular settings of the cams 60, 92 and 105 and cam disc 153 are such that in each cycle the pressure unit cam 60 operates its contact device first, then the temperature unit cam operates its contact device, and then the humidity unit cam operates its contact device. The projection 154 of cam disc 153 operates just prior to cam 60 of the pressure unit at the lowest end of its range, that is, just before the pressure unit can cause a circuit interruption corresponding to the barometric pressure at the start of the flight; and the dual projections 154 and 155 of cam disc 153 operate just after the high end of the range of the temperature unit. The single reference markings 157 on the chart are created by the projection 154, and the double motor-speed-indicating marks 158 by the dual projections 155 and 156. If the motor speed is constant, the speed of the recorder motor also being constant, there will be no change in successive cycles of operation in the time interval between the instant at which the reference signal caused by the projection 154 creates a mark 157 and the instant at which the speed indicating signal caused by the projections 155 and 156 creates a double mark 158, and, as a consequence, the double line 158 will have no horizontal displacement but will appear much as shown in Fig. 6. Any increase in the speed of the motor will be indicated by displacement of the double line 158 to the left, and any decrease in the motor speed will cause line 158 to be displaced to the right.

Under certain conditions, as in a radio meteorological transmitter such as illustrated by Fig. 28, in which the meteorological units have normally-open-circuit contact assemblies of the kind shown by Figs. 18 and 19, it is often desirable to make the cam projection 154 of sufficient peripheral length greater than that of projections 155 and 156 so that a signal of sufficient duration will be transmitted thereby to enable an operator at the ground station to keep the radio receiver accurately tuned to the transmitting apparatus. The reference line will then appear much as the line 157′ shown in Fig. 7.

When the contact assemblies of the meteorological units are of the normally open-circuit type as in Figs. 18 and 19, the contact members of the contact assembly of the indexing device 34 will be normally out of engagement and will be put into momentary engagement by the projections on the cam disc to close the circuit, and such normally-open-circuit contact assembly will be connected in parallel with the parallel-connected contact assemblies of the meteorological units as shown in Fig. 28.

The speed check signal may serve as an identifying signal, since by providing the indexing cam disc 153 with the proper peripheral projections the signal interruptions or impulses caused thereby may be such as to produce a check line 158 on the recorder chart of an identifying character, such as, for example, a line of two dots or of three dots or of a dash and dot. Under certain conditions, especially in connection with military operations, it is desirable to operate at the same time two or more radiometeorograph transmitters using radio carrier frequencies not greatly separated from each other; and in such case there is always the possibility that the radio transmitters will drift in frequency and possibly cross each other, making it difficult to determine which radiometeorograph transmitter is being followed. The identifying signal removes this difficulty.

Any suitable light weight motor may be used for driving the shaft 125 which operates the telemetering units. I prefer to use a motor of the kind shown in Figs. 20 to 26. This motor is of the general type disclosed and claimed in the Wallace U. S. Patent No. 1,985,357, and the Wallace and MacKay U. S. Patent No. 2,181,841.

As shown by Figs. 20 to 26, the rotor 160 of the motor is a magnet having a north pole and a south pole, which is most desirably circular in order to secure dynamic balance and strain, and thereby greater speed of rotation than if of the bar magnet type, and which is best made from a magnetic alloy commercially known as Alnico in view of this alloy's high magnetic flux density and high resistance to demagnitization from stray fields or vibratory effects. Due to these improved magnetic properties, a smaller and lighter weight rotor can be used than if the rotor were made of other magnetic materials of which I have knowledge.

The rotor extends into a magnetic field created by an air-core solenoid 161 which serves as the stator, and which, as shown, in the interest of weight reduction, consists of a self-supporting insulated and varnish-impregnated winding of fine wire mounted to one side of the rotor shaft 162. Obviously, for a more efficient though slightly heavier motor, two stator windings might be employed as shown in the above cited U. S. patents.

The rotor shaft is made from a hard or tool steel or other suitable metal, and the rotor is mounted thereon by means of a suitable bushing. As shown by Fig. 22, the shaft has reduced ends which are journaled in two-piece jeweled bearings carried by holders 163 and 164 which are mounted one in the motor bed plate 36 and the other in a flange of a frame 165 of brass or aluminum or other suitable material which is secured to and extends out at right angles from the motor bed plate 36. The bearing holder 164 is seated in the bed plate, and the holder 163 is adjustably mounted in the flange of the frame. The bearings are of usual form, each having a ring stone 166 and a cap stone 167 which may be made from synthetic sapphire, ruby or garnet, or other suitable material, and the bearings are set so as to permit of sufficient longitudinal movement of the shaft to obviate possibility of binding of the shaft which might otherwise result from unequal expansion or contraction of the shaft and the supporting frame when extreme changes in temperature are encountered. Due to the low temperatures at which these motors have to operate, only a very small amount of lubrication, or no lubrication at all, is permissible, and bearings of the type illustrated have been found most advantageous for this condition of service. The bearing holders may be made of brass or other suitable material, and the stones may be secured in position by a slight rolling or swaging over of the holder material about the outer edges of the ring stones. To provide for adjustment of the bearing holder 163, it has a threaded shank or body which screws through a tapped hole in the frame and through a tapped hole in a flat spring 168, the ends of which bear against the outside of the frame and which acts as a locking member to maintain the bearing member in fixed position against the effects of vibration. The stator coil 161 is secured to the frame 165 by means of clamping strips of Bakelite or other insulating material held by screws 169.

The commutating contacts of the motor are provided by a movable contact member 170 and a stationary, or substantially stationary, contact member 171. The movable contact member 170 is formed by a piece of spring silver wire secured to the frame 165 by a grounding screw 172 and the free end of which extends past an eccentric, or cam, portion 173 of the rotor shaft and is tensioned to bear against this eccentric portion of the shaft during at least a part of the revolution of the shaft. The stationary contact member 171 is formed by a strip of spring silver one end of which is insulated from the frame and secured by a screw 174 and the free end of which extends in position to be engaged by the end of the movable contact member when the latter is moved by the eccentric part of the rotor shaft. This contact strip 171 is tensioned toward the end of the movable contact wire and is held in position for engagement by the movable contact by an adjusting screw 175 carried by a stationary metal strip 176 also secured by the screw 175 and insulated from the frame. As the rotor shaft rotates, therefore, intermittent contact will be made between the movable and stationary contact members, and, the eccentric portion 173 of the shaft being properly positioned angularly in relation to the plane of the stator coil and the magnetic axis of the magnet, rotation of the rotor will result. If the motor is intended to run for a long time without cleaning of the contacts, it is desirable, in order to reduce or eliminate sparking at the contacts 170 and 171, to have the contacts shunted with a small condenser resistor unit or to provide a high resistance in parallel with the coil 161.

The rotor shaft carries a small pinion 177 from which through a suitable train of reduction gearing 178 the driving shaft 125 is driven at the desired speed, to provide, for instance, transmission of two cycles of meterological data per minute. The motor may, of course, be operated at different speeds, or different gear ratios may be employed, to provide for any desired speed of rotation of the driving shaft 125.

The circuit of the motor is substantially the same as that shown for the motor mechanisms in the patents cited above, the current through the motor flowing in a circuit as follows: from a connection on a plate 179 of insulating material to and through the coil 161, thence to the frame 165 and then through the movable contact 170 to the stationary contact 171, and then back to the opposite side of the source.

Instead of a circuit interrupting governor means, it has been found more desirable in many cases to use a governor of the friction type as shown in order to insure very accurate speed regulation under the temperature variations to which the motor is subjected in use and which result in varying the ohmic resistance of the stator field winding and in lowering the battery voltages to some extent. A governor of this type also insures a somewhat smoother action, and, furthermore, reduces weight and space requirements. This governor as shown comprises a rod 185 of brass or other suitable material mounted fast on the rotor shaft to extend at right angles therefrom in both directions, a weight 186 slidably mounted on one end of the rod and under tension to move toward the shaft 162 by a coil spring 187, and a counterweight 188 which is longitudinally adjustable on the threaded other end portion of the rod. One end of the spring 187 is screwed onto a threaded boss on the inner end of the weight 186. The other end of the spring is reduced and engages a threaded portion of the rod 185. This small end of the spring may thus be adjusted longitudinally of the rod for adjustably varying the pull of the spring on the weight. The outer end of the weight 186 carries a small contact piece or pad 189 of suitable friction material, such as cork or leather, which may be set in and cemented or otherwise secured in a recess in the outer end of the weight.

As the shaft rotates, centrifugal force tends to cause the weight 186 to move outward on the rod 185, this movement being resisted by the spring 187 and limited by a coacting friction ring 190 which is mounted in the frame 165 and positioned concentric with the axis of the motor shaft and in the plane of movement of the weight 186. The ring has a smooth inner surface, and for lightness is desirably made of thin brass or other suitable metal reinforced by having flanged edges, as appears from Fig. 21. When the motor reaches a certain speed, determined by the adjustment of spring 187, the friction-shod end of weight 186 engages with the inner surface of ring 190, thereby braking the motor and by conventional governor action maintaining the motor speed accurately within predetermined very close limits.

The motor is not provided with any polarizing magnet or other biasing means as there is no need to make it self-starting since it runs continuously while in flight and can be started prior to flight either directly by hand or by imparting a circular motion to the whole apparatus. A click spring 191 which meshes with the last gear 192 of the motor train 178 serves to prevent reverse movement of the motor due to incorrect connection to the power source or to manual operation. Such reversal of the motor might result in damage to the telemetering contact assemblies.

This motor is remarkably smooth and continuous in its operation, and possesses many times the power obtainable from clockwork mechanisms of comparable weight, the complete motor weighing only in the neighborhood of 40 or 50 grams for the radiometeorograph transmitter shown. Furthermore, no lubrication is required for its bearings, and its speed is substantially unaffected by temperature changes. As will be hereinafter made apparent, the speed of the driving means is extremely important in all types of time interval metering systems and directly affects the accuracy of the results obtained. Motors such as above described have been found to have speed characteristics superior to synchronous clock motors operated from so-called commercial power lines. By "superior characteristics" is meant that over short periods of time their speed is much more constant than that obtained over like intervals from commercially energized synchronous motors. It is the cycle to cycle variation that is important in telemetering, and therefore a slight but uniform drift in speed in one direction or the other is not objectionable, short and erratic variations in speed being the kind which destroy the accuracy of metering.

Referring now to the wiring diagram of Fig. 27: The three containers 10, 11 and 12 housing the various parts of the complete radiometeorograph transmitter are indicated by dotted lines in this figure. A combined storage "A" and "B" battery 200 is shown as in container 10; the contact assemblies and operating cams of the pressure, humidity and temperature units and of the indexing device, and the motor and driving shaft and gears between the shaft and cams are indicated as in container 11; and there is indicated as in container 12 a radio transmitter of the Colpitts type, well known in the art of radiometeorography and radio communication. As any suitable type of radio transmitting apparatus and circuits may be used in radiometeorograph transmitters according to the invention, no description of the radio transmitter shown or of its operation is needed for a full understanding of the invention.

The contact assemblies of the meteorological units as indicated in this figure are of the closed circuit type, transmitting a continuous signal during each cycle of operation except for momentary interruptions by the meteorological units and the indexing device, the contact assemblies of the meteorological units and of the indexing devices being connected in series.

The operation of the radiometeorograph transmitter as illustrated by this figure is as follows:

Current flows from the positive side of the 6-volt A battery section of the combined storage battery 200 through wire 201 and one sleeve of the socket 24 to the coacting prong of plug 22, and then through a conductor 202 to the positive 6-volt terminal 132 on the terminal strip 130, and then by a lead 203 to one side of the driving motor in the housing 30. The other side of the motor is connected by wire 204 to the negative 6-volt terminal 131 and then by conductor 205, another prong of the plug 22 and coacting sleeve of socket 24 and wire 206 to the negative side of the low voltage section of the battery.

Current at potential of 6 volts is also caused to flow in a circuit starting at the positive terminal 132 through conductor 207, a sleeve and prong of socket 23 and plug 25, and wire 208 to one side of the filament, or heater, in the vacuum tube 209 of the radio transmitter, and returning from the other side of the filament through conductor 210, another prong and sleeve of plug 25 and socket 23, and by conductor 211 to the negative terminal 131.

By these circuit connections from the 6-volt section of the battery, the motor is caused to operate to drive the shaft 125 by which the telemetering cams 62, 94 and 106 and the indexing cam disc 153 are driven; and in addition, the filament and cathode of the vacuum tube 209 are energized.

Plate voltage is applied to the radio transmitter from the high voltage B battery section as follows: Current flows from the positive side of the B battery through conductor 212 and a sleeve and prong of socket 24 and plug 22, and by wire 213 to terminal 133 of the terminal strip 130; and thence by wire 214 to spring contact rod 73 of the contact assembly of the temperature unit, and, the circuit being normally closed through this contact assembly, current flows from its spring contact rod 75 through wire 215 to the contact assembly of the humidity unit, and thence by wire 216 to the contact assembly of the pressure unit, and thence by wire 217 to the contact assembly of the indexing device, and thence by wire 218 to terminal 134, from which current flows through wire 219, a sleeve and prong of socket 23 and plug 25, and thence by way of the radio frequency choke coil 220 and wires 221 and 222 to the plate of vacuum tube 209.

The return circuit to the negative side of the B battery is by way of the circuit connections before described between the filament of tube 209 and the positive side of the A battery to the connecting point 223 and thence by conductor 224 to the negative side of the B battery.

The radio transmitter will thus emit electromagnetic waves from its antenna 18 except when the plate current of vacuum tube 209 is momentarily interrupted by the operation of one or another of the contact assemblies by their cams 60, 92, 105 and 153, and as these momentary interruptions caused by the cams of the pressure, humidity and temperature units bear a significant time relationship to the positions assumed by the pressure-, humidity- and temperature-responsive elements of these units, and to the speed of the motor, they can serve to actuate or control the stylus of the recording apparatus at a distant meteorological station in the known way.

Fig. 28 is similar to Fig. 27 except that it shows a normally open-circuit apparatus in which the contact assemblies are of the type illustrated by Figs. 18 and 19 and the several contact assemblies are connected in parallel instead of in series as hereinbefore pointed out. In the circuit shown the frame of the motor is most desirably insulated from the chassis as one side of the chassis serves as a connection to the positive side of the A battery, or else the wiring of the motor and the circuit of Fig. 28 may be revised so that the frame of the motor acts as its positive terminal.

Referring now to Fig. 28, it will be seen that with exception of the keying circuits controlled by cams 60, 92, 105 and 153, the circuit connections are mostly as in Fig. 27 and have the same reference numerals. Plate voltage is, however, applied to the vacuum tube 209 as follows: From the positive side of the B section of battery 200 current flows through the conductor 225, sleeve of socket 24, prong of plug 22, conductor 226, sleeve of socket 23, prong of plug 25, and through the choke coil 220 and wires 221 and 222 to the plate of tube 209; and the return connection from the negative or cathode side of the tube 209 is effected by way of conductor 208, prong of plug 25, sleeve of socket 23, and wire 227 to terminal 134 which is grounded to chassis 35 by lead 228. Current then flows through the chassis and through the contact assembly of any one of the meteorological units the contacts of which may be in momentary engagement, or through the contact assembly of the indexing device when its contacts are in momentary engagement, and thence by wires 235 and 236 to terminal 133, and by conductor 237, prong and sleeve of plug 22 and socket 24, and by conductor 238 to the negative side of the B section of the battery.

Intermittent radio impulses will thus be emitted by the radio transmitter as the circuit is momentarily closed by the meteorological units and by the indexing device, the time intervals between the reference signal and the metering signals and the motor speed check signal indicating the conditions of pressure, humidity and temperature and also the speed of the motor.

For receiving the radio signals, I prefer to employ what is known as a super-regenerative receiver because of its great sensitivity at the ultra-high frequencies commonly used for radiometeorographic transmission; also, because receivers of this type have inherent automatic volume control properties and are quite broad in their tuning so that small departures from the ground level frequency of the radiometeorograph transmitter does not prevent reception of the signals. Furthermore, if the frequency of the transmitter continues to drift it is quite easily followed on account of the broad tuning that is characteristic of super-regeneration.

For operating the stylus of the recording device, which is usually at a meteorological station, I prefer to employ a relay having both front and back contacts and arranged in a circuit of the type of that of U. S. Patent 2,165,062 of J. R. MacKay. In the systems described in that patent the differential in the "rush" currents of the superregenerative receiver, as controlled by the carrier wave of the radio transmitter, operate the relay, and as the relay is provided with both front and back contacts, the stylus may be electrically controlled for operation either on a received radio impulse or on the interruptions of an otherwise continuous radio signal.

The particular form of radio receiver and recording device to be used with radio meteorograph transmitters of the invention form no part of the invention. It may be pointed out, however, that the type of recording device which it is preferred to use with the new radiometeorograph transmitter has a synchronizing means whereby the pen arm of the recorder immediately returns rapidly to its left hand position right after receipt of the double motor-speed check signal and then is locked at that point until the single reference signal is received. Receipt of this reference signal releases a latch and permits the pen arm to travel at a constant speed over the surface of the chart in a right hand direction, thereby insuring a record the departure of which from complete accuracy is dependent upon the negligible cycle to cycle relative variations in speed of the motors of the transmitter and the receiver, and not on the cumulative variation over the entire period of the flight. Furthermore, in the preferred form of recorder there is provided a means, either manual or automatic, for varying the speed of the motor which drives the pen arm so that if there is any departure from the vertical of the line formed by the double speed-check signal the motor can be immediately speeded up or slowed down to keep the distance between the reference line and the speed-check line constant, thereby synchronizing the speed of the recorder motor with the motor of the distant radiometeorograph transmitter.

If the radiometeorograph transmitter is of the form shown by Fig. 4, having a motor-driven fan for maintaining an air current past the humidity and temperature responsive elements, the fan motor will have its terminals connected in parallel with the terminals of the driving motor so that both operate on the 6-volt battery.

When the meteorological units have contact assemblies of the normally-closed-circuit type, as shown by Figs. 8 to 17, the instrument may be made to serve for providing indications of wind velocity and direction, as it can readily be followed with certain types of radio direction finding apparatus due to its substantially continuous signal. In many cases, however, only indications of pressure, humidity and temperature are wanted, and in such cases the use of meteorological units having the normally-open-circuit contact assemblies of Figs. 18 and 19 has the advantage that, since the meteorological measurements are transmitted by short radio impulses, the amount of power required to operate the radio transmitter is much less, and a material saving can be effected in both the weight and cost of the batteries, which in turn is reflected in the size of balloon required and the amount of inflating gas used. And, further, because of the reduction in weight of the batteries, if the balloons used are of the same size as used for the instruments having contact assemblies of the normally closed-circuit type, they may be inflated to a lower pressure and thereby enabled to reach greater heights before they burst.

It will be understood from the foregoing description that the transmitter herein described, being made up of parts which are interchangeable, has the advantage that the instrument is readily repairable in the field, and that identical meteorological measurements are obtained with interchangeable unitary parts, a result not obtainable with the instruments of the prior art. Further advantages of the new apparatus are, that no correction need be made of the measurements recorded as the result of the transmitted signals, the record being directly in terms of pressure, humidity and temperature to be used without the application of any corrective factors, so that the record of a flight may be evaluated as received while the flight is in progress; that the apparatus as a whole is of comparatively rugged construction and reliable in operation, and is made up of parts adapted for mass production; and that the meteorological units are easily calibrated and adjusted, and are more accurate in their measurements than those of the prior art because of the play-free connections between the responding elements and their contact assemblies, the use of levers, linkages, cords and pivots being largely eliminated, thereby removing the principal sources of error in the prior art instruments. Also, the new instrument has a linear, or straight-line, characteristic, and may be adjusted to position its record on predetermined portions of the chart on which its signals are recorded; and the meteorological units can have their response modified by intentional deforming of their operating cams to expand or reduce the scale of any desired portion of the measurement range. For example, a radiobarograph transmitter used in conjunction with other apparatus for the study of cosmic rays might have its operating cam formed to produce precise and easily readable records of a balloon's altitude at very low pressures even below 20 millibars.

It is, of course, to be understood that many parts or features of the invention may be used independently of other parts and features and in combinations other than as shown and for other purposes. The meteorological telemetering units are obviously adapted for independent use. For example, the pressure unit might be used in apparatus carried by small free balloons for determination of wind velocity and direction in conjunction with radio direction finding means, or used in connection with the study of cosmic rays.

The term "instrument" as used in the claims is not to be understood as implying that the device so termed is a separately removable and replaceable unit unless it is otherwise so defined in the claims.

What is claimed is:

1. In a radiometeorograph transmitter, a meteorological transmitter which comprises a driving motor, a driving shaft driven by said motor, a plurality of telemetering transmitting instruments each having an element responsive to changes in an atmospheric condition and a contact assembly the position of which is controlled by said element and a rotary cam for coacting with said contact assembly, and driving connections between said shaft and the cam of each of said telemetering instruments, each of said telemetering instruments being a standardized self-contained unit separately removable and replaceable and capable of independent adjustment and calibration.

2. In a radiometeorograph transmitter, a meteorological transmitter which comprises, a plurality of elements responsive to changes in different atmospheric conditions, a contact assembly comprising two relatively movable members for each of said elements the position of which as a whole is controlled by the element, a rotary cam for operating each of said contact assemblies, a motor for driving said cams, said cams being separately adjustable for adjustably varying the angular relation of the cams to each other, and means for separately adjusting each of said contact assemblies with relation to its operating cam.

3. In a radiometeorograph transmitter, a meteorological transmitter which comprises, a plurality of elements responsive to changes in different atmospheric conditions, a contact assembly comprising two relatively movable members for each of said elements the position of which as a whole is controlled by the element, a rotary cam for operating each of said contact assemblies, a motor for driving said cams, and means for separately adjusting each of said contact assemblies with relation to its operating cam.

4. In a radiometeorograph transmitter, a meteorological transmitter which comprises a cam, a driving motor therefor, an element responsive to changes in an atmospheric condition, and a contact assembly comprising two relatively movable members for coacting with said cam and the position of which contact assembly as a whole with relation to the cam is controlled by said element, the contact assembly and the element being mounted for adjustment together for adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly.

5. In a radiometeorograph transmitter, a meteorological transmitter which comprises a cam, a driving motor therefor, an element responsive to changes in an atmospheric condition, and a contact assembly comprising two relatively movable members for coacting with said cam and the position of which contact assembly as a whole with relation to the cam is controlled by said element, the contact assembly and the element being mounted for adjustment together for adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly, and the contact assembly and the element being relatively adjustable to vary the magnitude of movement imparted to the contact assembly for a given change in said atmospheric condition.

6. In a radiometeorograph transmitter, a meteorological transmitter which comprises a cam, a driving motor therefor, an element responsive to changes in said atmospheric condition, and a contact assembly comprising two relatively movable members for coacting with said cam and the position of which contact assembly as a whole with relation to the cam is controlled by said element, the contact assembly and the ele-

ment being relatively adjustable to vary the magnitude of movement imparted to the contact assembly for a given change in said atmospheric condition.

7. In a radiometeorograph transmitter, a meteorological transmitter which comprises a plurality of elements responsive to changes in different atmospheric conditions, a plurality of circuit-controlling contact assemblies each of which comprises a cam-operated contact member and a cooperating contact member, said members being relatively movable, and play-free connecting means between each of said elements and one of said contact assemblies whereby the position of the contact assembly as a whole is varied in accordance with changes in an atmospheric condition.

8. In a radiometeorograph transmitter, a meteorological transmitter which comprises an element responsive to changes in an atmospheric condition, a circuit controlling contact assembly which comprises a cam-operated contact member and a cooperating contact member, said members being relatively movable, and play-free connecting means between said element and said contact assembly whereby the position of the contact assembly as a whole is varied in accordance with changes in said atmospheric condition.

9. A meteorological transmitter for a radiometeorograph transmitter, comprising a driving motor, a plurality of telemetering transmitting instruments each having an element responsive to changes in an atmospheric condition and a contact assembly the position of which is controlled by said element and a rotary cam driven by said motor for coacting with said contact assembly to cause a condition-indicating signal-producing circuit change, and means operated by said motor for causing a reference-signal-producing circuit change at the beginning of each cycle of operations and a motor-speed-check-signal-producing circuit change at the end of each cycle.

10. A meteorological transmitter for a radiometeorograph transmitter, comprising a driving motor, a plurality of telemetering transmitting instruments each having an element responsive to changes in an atmospheric condition and a contact assembly the position of which is controlled by said element and a rotary cam driven by said motor for coacting with said contact assembly to cause a condition-indicating signal-producing circuit change, and means operated by said motor for causing a reference-signal-producing circuit change at the beginning of each cycle of operations and a motor-speed-check-signal-producing circuit change at the end of each cycle for producing a signal having a characteristic identifying the radiometeorograph transmitter.

11. A meteorological transmitter for a radiometeorograph transmitter, comprising a driving motor, a plurality of telemetering transmitting instruments each having an element responsive to changes in an atmospheric condition and a contact assembly the position of which is controlled by said element and a rotary cam driven by said motor for coacting with said contact assembly to cause a condition-indicating signal-producing circuit change, and indexing means comprising a contact member and a cam disc driven by said motor having a cam formation for operating the contact member to cause a reference-signal-producing circuit change and a cam formation for operating the contact member to cause a motor-speed-check-signal-producing circuit change.

12. A meteorological transmitter for a radiometeorograph transmitter, comprising a driving motor, a plurality of telemetering transmitting instruments each having an element responsive to changes in an atmospheric condition and a contact assembly the position of which is controlled by said element and a rotary cam driven by said motor for coacting with said contact assembly to cause a condition-indicating signal-producing circuit change, and indexing means comprising a contact member and cam means driven by said motor having a cam formation for operating the contact member to cause a reference-signal-producing circuit change and a cam formation for operating the contact member to cause a motor-speed-check-signal-producing circuit change, said last mentioned cam formation being shaped to cause an identification signal identifying the radiometeorograph transmitter.

13. In a radiometeorograph transmitter, a meteorological transmitter which comprises a plurality of elements responsive to changes in different atmospheric conditions, a plurality of operating cams, and a circuit-controlling contact assembly for each of said elements the position of which with relation to one of said cams is controlled by the element, said contact assemblies being normally in closed circuit condition and being connected in series in a circuit to the radio transmitter and each of said contact assemblies having a cam-engaging member and being formed to open said circuit momentarily when its cam-engaging member is moved by its cam, whereby the radio transmitter is caused to transmit a continuous signal during successive cycles of operation with momentary interruptions indicating the changes in the atmospheric conditions.

14. In a radiometeorograph transmitter, a meteorological transmitter which comprises an element responsive to changes in an atmospheric condition, an operating cam, and a circuit-controlling contact assembly having a cam-engaging member and the position of which contact assembly with relation to the cam is controlled by the element, said contact assembly being normally in closed circuit condition and being connected in circuit with the radio transmitter and being formed to open the circuit momentarily when its cam-engaging member is moved by the cam, whereby the radio transmitter is caused to transmit a continuous signal during successive cycles of operation with momentary interruptions indicating the changes in the atmospheric condition.

15. In a radiometeorograph transmitter, telemetering means comprising an element responsive to an atmospheric condition, an operating cam, and a contact assembly operated by said cam and the position of which with relation to the cam is controlled by said element, said contact assembly comprising a movable cam-engaging contact member, two electrically connected contact terminals with one of which said contact member is normally in circuit-closing engagement, and with the other of which contact terminals said contact member comes into engagement when moved by the cam away from the first contact terminal, whereby a normally closed circuit is opened momentarily when said contact member is moved by the cam.

16. In a telemetering transmitting device, a circuit-controlling contact assembly, an operating cam, and means for positioning the contact assembly with relation to the cam in accordance with changes in a measured condition, said contact assembly comprising a movable cam-engaging contact member, two electrically connected contact terminals with one of which said contact member is normally in circuit-closing engagement, and with the other of which contact terminals said contact member comes into engagement when moved by the cam away from the first contact terminal, whereby a normally closed circuit is opened momentarily when said contact member is moved by said cam.

17. In a telemetering transmitting device, a circuit-controlling contact assembly, an operating cam, and means for positioning the contact assembly with relation to the cam in accordance with changes in a measured condition; said contact assembly comprising a support member, a movable cam-engaging contact member, and a second contact member having a normal position with relation to the support member and adapted to be moved by the first said contact member when the latter is moved by the cam.

18. In a telemetering transmitting device, a circuit-controlling contact assembly, an operating cam, and means for positioning the contact assembly with relation to the cam in accordance with changes in a measured condition; said contact assembly comprising a support member, a movable cam-engaging contact member, and a second contact member having a normal position with relation to the support member and having two spaced contact terminals through which the first said contact member extends and with one of which it is normally in engagement, the first said contact member being adapted when operated by the cam to move away from the contact terminal with which it is normally in engagement and into engagement with the other contact terminal and thereafter to move the second contact member with relation to the support member, whereby a normally closed circuit is opened momentarily when the first said contact member is moved by the cam.

19. In a telemetering transmitting device, a circuit-controlling contact assembly, an operating cam, means for positioning the contact assembly with relation to the cam in accordance with changes in a measured condition; said contact assembly comprising a support member, a movable cam-engaging contact member, and a second contact member having a normal position with relation to the support member and adapted to be moved by the first said contact member when the latter is moved by the cam; and adjusting means for adjusting the normal position of the contact assembly with relation to the cam to vary the time of operation of the contact assembly.

20. In a telemetering transmitting device, a circuit-controlling contact assembly, an operating cam, and means for positioning the contact assembly with relation to the cam in accordance with changes in a measured condition; said contact assembly comprising a support member having a contact terminal, a movable cam-engaging contact member, and a second contact member normally engaging the contact terminal on the support member and which is moved out of engagement with the contact terminal of the support member by the first said contact member when the latter is moved by the cam, whereby a normally open circuit is momentarily closed when the first said contact member is moved by the cam.

21. A barometric telemetering transmitting instrument, comprising a pressure capsule which is expansible and contractible in response to changes in atmospheric pressure, a rotary cam, a support member connected to one side of said capsule, a pivotally mounted transmitter arm having a play-free connection to the other side of said capsule, and a contact assembly carried by said arm for coacting with the cam, said contact assembly comprising a support member and a movable cam-engaging contact member and a second contact member having a normal position with relation to the support member and adapted to be moved by the first said contact member when the latter is moved by the cam.

22. A barometric telemetering transmitting instrument, comprising a pressure capsule which is expansible and contractible in response to changes in atmospheric pressure, a rotary cam, a U-shaped supporting member to one arm of which one side of the capsule is connected, a transmitter arm having a play-free pivotal connection with the other arm of said U-shaped member and having a play-free connection with the other side of the capsule, a contact assembly for coacting with the cam carried by said transmitter arm, and means for adjusting said U-shaped member angularly for adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly.

23. A barometric telemetering transmitting instrument, comprising a pressure capsule which is expansible and contractible in response to changes in atmospheric pressure, a rotary cam, a U-shaped supporting member to one arm of which one side of the capsule is connected, a transmitter arm having a play-free pivotal connection with the other arm of said U-shaped member and having a play-free connection with the other side of the capsule, a contact assembly for coacting with the cam carried by said transmitter arm, means for adjusting said U-shaped member angularly for adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly, and means for adjusting said U-shaped member longitudinally of the transmitter arm and for adjusting the contact assembly longitudinally of the transmitter arm for varying the magnitude of movement imparted to the contact assembly for a given change in atmospheric pressure.

24. A telemetering transmitting instrument, comprising an element responsive to changes in atmospheric humidity, a rotary cam, a pivotally mounted support member to which one end of said element is connected, a contact assembly carried by said support member for coacting with the cam, a spring acting on the support member to maintain said element under constant tension, and adjusting means for adjustably varying the position of said element and thereby adjusting the contact assembly with relation to the cam.

25. A telemetering transmitting instrument, comprising a temperature-responsive element formed by a bi-metallic strip rigidly supported at one end, a rotary cam, and a contact assembly carried by the other end of said element for coacting with the cam.

26. A telemetering transmitting instrument, comprising a temperature-responsive element formed by a bi-metallic strip rigidly supported

at one end, a rotary cam, a contact assembly carried by the other end of said element for coacting with the cam, and means for angularly adjusting said element and thereby adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly by the cam.

27. A telemetering transmitting instrument, comprising a temperature-responsive element formed by a bi-metallic strip rigidly supported at one end, a rotary cam, a contact assembly carried by the other end of said element for coacting with the cam, and means for adjusting said element longitudinally and adjusting the cam-engaging member of the contact assembly relatively to said element to vary the magnitude of movement imparted to the contact assembly for a given temperature change.

28. A telemetering transmitting instrument, comprising a temperature-responsive element formed by a bi-metallic strip rigidly supported at one end, a rotary cam, a contact assembly carried by the other end of said element for coacting with the cam, means for angularly adjusting said element and thereby adjusting the contact assembly with relation to the cam to vary the time of operation of the contact assembly by the cam, and means for adjusting said element longitudinally and adjusting the cam-engaging member of the contact assembly relatively to said element to vary the magnitude of movement imparted to the contact assembly for a given temperature change.

29. A telemetering transmitting instrument, comprising a temperature-responsive element formed by a bi-metallic strip rigidly supported at one end by having the end edge of the strip entered into slots in spaced plates and having a strain-equalizing slot extending from its supported end and for a major part of its length, a rotary cam, and a contact assembly carried by the other end of said element for coacting with the cam.

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