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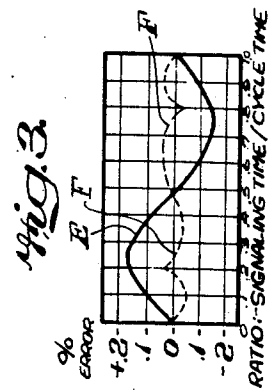
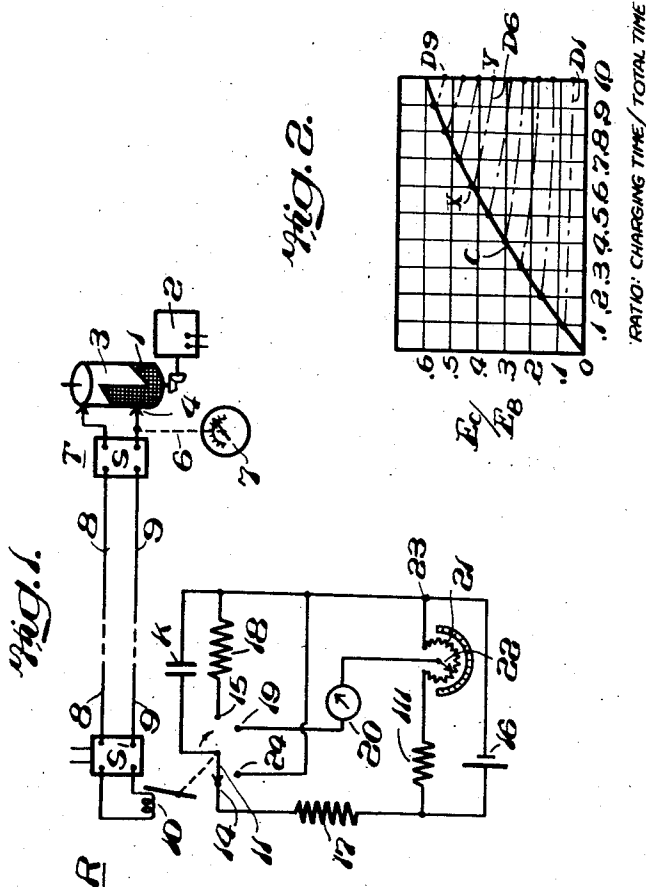
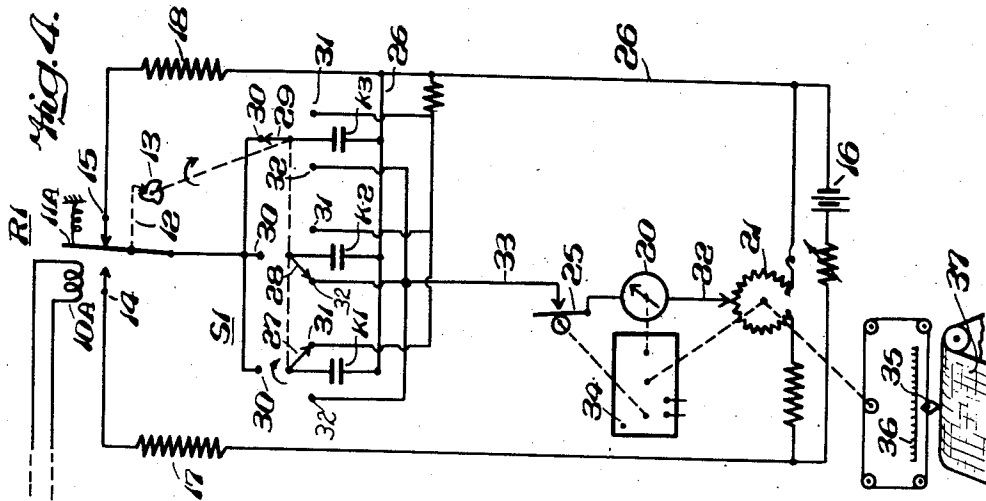
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2,336,929

TELEMETRIC SYSTEM

Filed June 19, 1942

6 Sheets-Sheet 1



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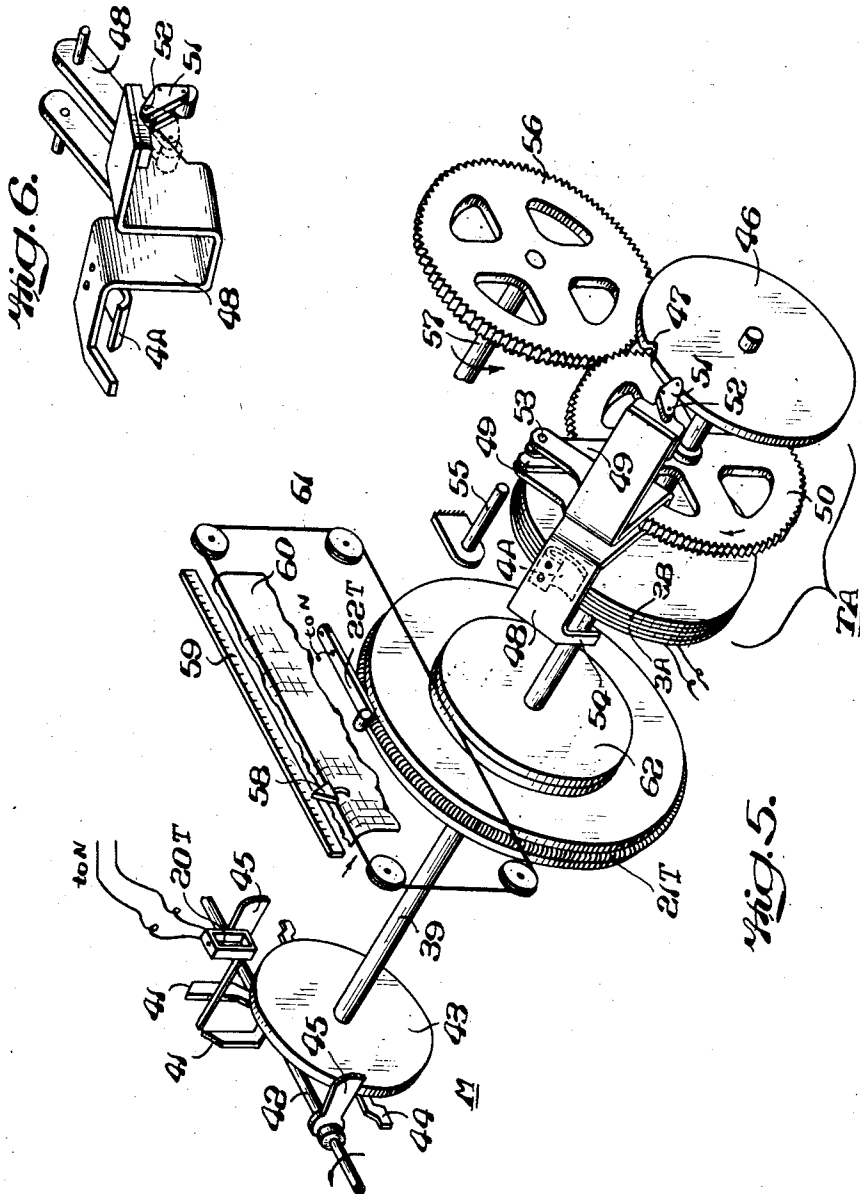
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TELEMETRIC SYSTEM

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6 Sheets-Sheet 2



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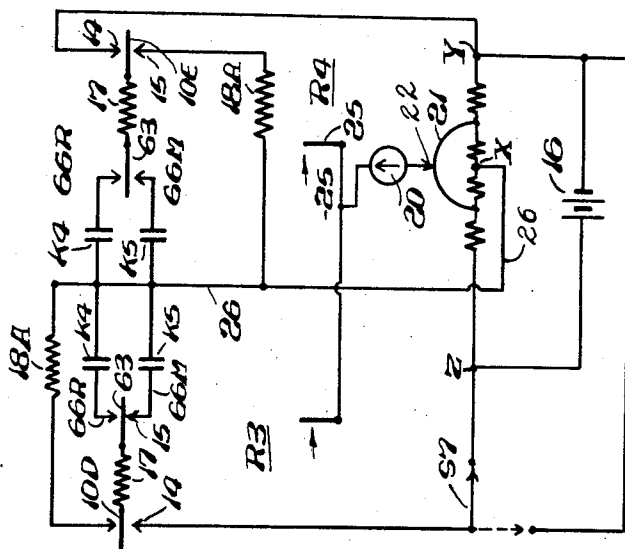
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TELEMETRIC SYSTEM

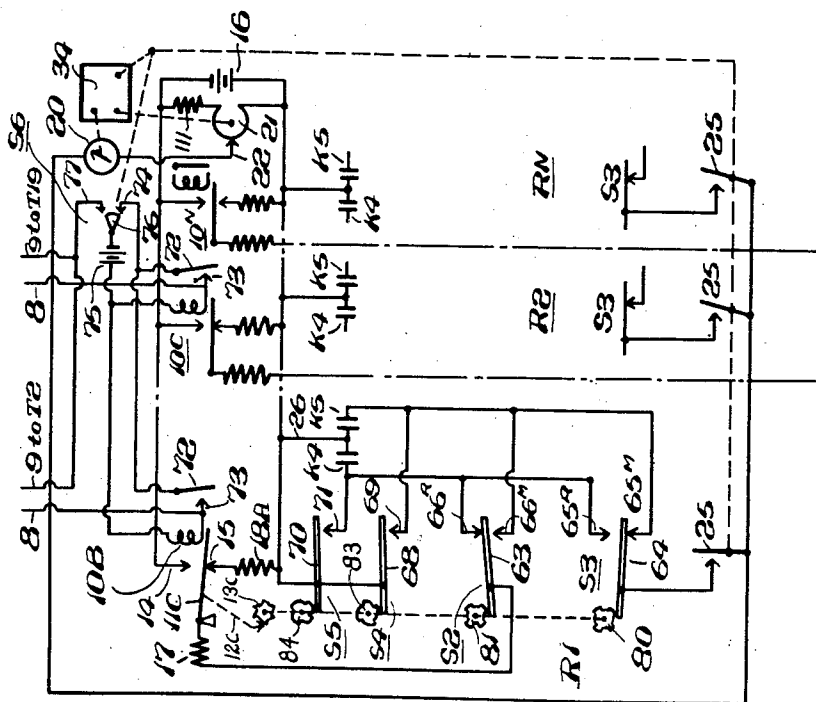
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6 Sheets-Sheet 3

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TELEMETRIC SYSTEM

Filed June 19, 1942

6 Sheets-Sheet 4

Fig. 10.

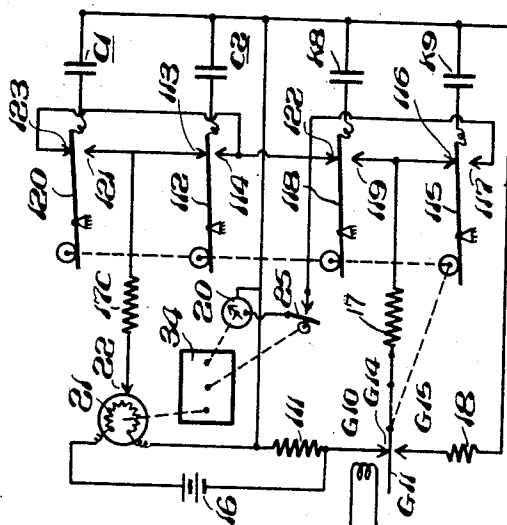
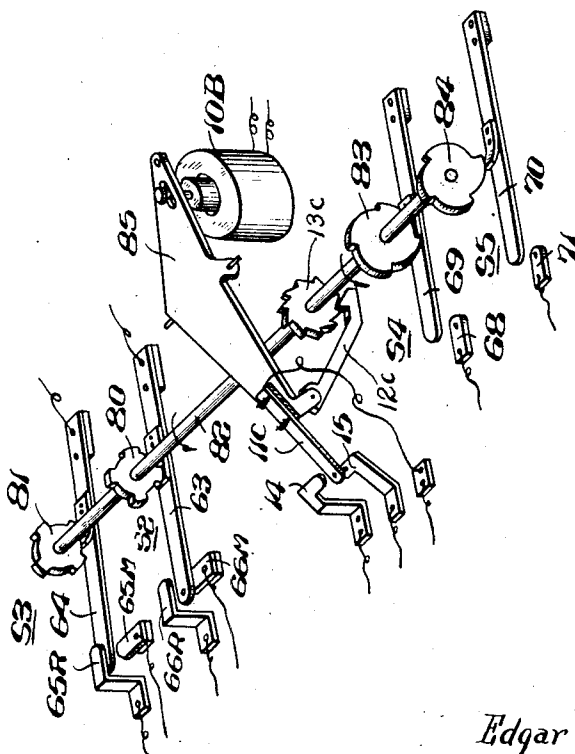


Fig. 8



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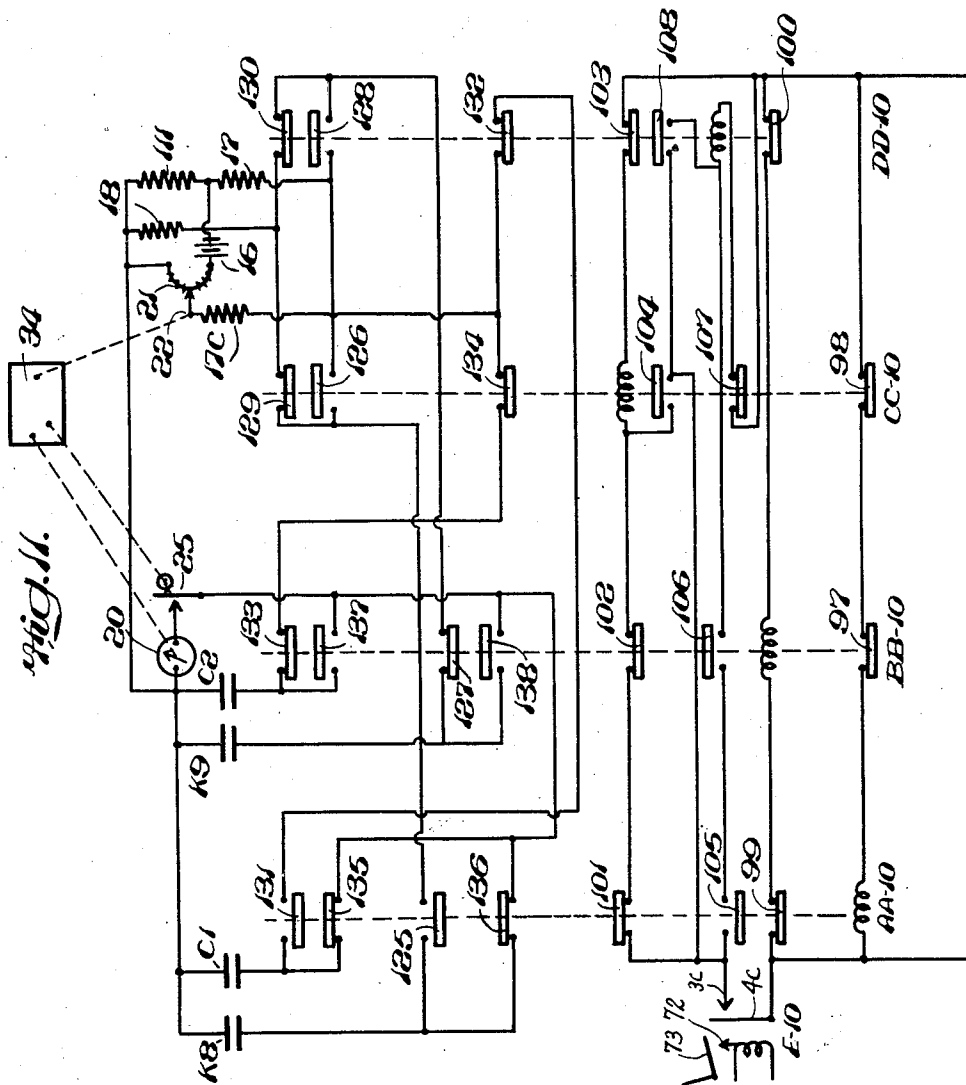
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TELEMETRIC SYSTEM

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6 Sheets-Sheet 5



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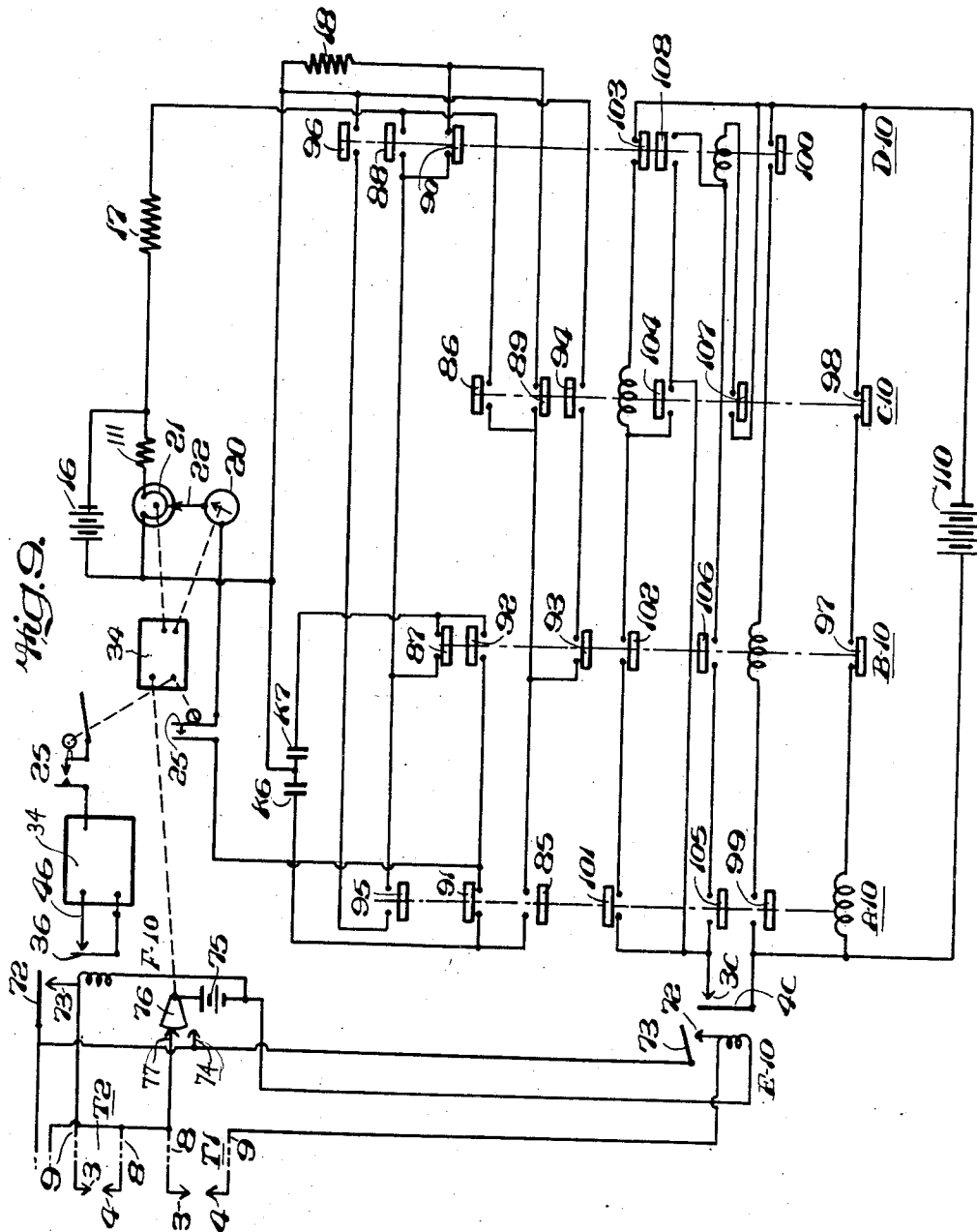
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TELEMETRIC SYSTEM

Filed June 19, 1942

6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,336,929

TELEMETRIC SYSTEM

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Application June 19, 1942, Serial No. 447,615

20 Claims. (Cl. 177—351)

My invention relates to systems for electrically indicating, recording or reproducing physical, electrical, mechanical or other magnitudes, including departures or displacements of devices in general, and relates particularly to telemetric systems, for the purposes aforesaid, of the types in which electrical impulses of durations related to aforesaid magnitudes are transmitted to more or less remote receiving stations.

In accordance with my invention, during successive signal cycles, each comprising an interval of time corresponding with the duration of one of said impulses and a complementary time interval, a reactance is first charged and then discharged to extents corresponding, respectively, with the durations of the impulse and of its said complementary interval, or vice versa, and then the residual charge of the reactance is impressed upon a suitable measuring circuit or network; more particularly, the time constants of the charging and discharging circuits are so related to each other that the magnitude of the residual charge or voltage of the reactance varies essentially proportionally to one of the aforesaid time intervals.

Further in accordance with my invention, the reactance-charging current is supplied by the same source provided to furnish current to the measuring circuit or network to eliminate necessity for recalibration of the system in compensation for relatively slow variation of the charging voltage.

Furthermore in preferred forms of my invention as utilized for telemetric recording, two or more reactances, preferably condensers, are employed, and their cycles (of charge, discharge and measurement of the residual charge) are suitably dephased so that it is not necessary to have or maintain synchronism of mechanism at the transmitting station with mechanism at the receiving station.

Further in accordance with my invention, to avoid excessive error when there is large departure from normal in the period or duration of a cycle, the residual voltage of the condenser is compared with the voltage of another condenser charged throughout the cycle from a source of voltage of magnitude varied as a function of the ratio of the duration of the impulse to the duration of the cycle.

My invention further resides in the methods and apparatus of the characters hereinafter described and claimed. For an understanding of my invention and for illustrations of various

forms thereof, reference is made to the accompanying drawings, in which:

Fig. 1 diagrammatically illustrates a telemetric system;

Figs. 2 and 3 represent operating characteristics hereinafter discussed;

Fig. 4 diagrammatically illustrates a telemetric recording system;

Fig. 5, in perspective, illustrates significant elements of a telemetric transmitter;

Fig. 6 is a perspective view of parts appearing in Fig. 5;

Fig. 7 is a circuit diagram of another telemetric receiver embodying my invention;

Fig. 7A illustrates a modification of Fig. 7;

Fig. 8, in perspective, illustrates constructional features of a relay diagrammatically shown in Fig. 7;

Figs. 9 and 10 are diagrams illustrating further modifications of my invention;

Fig. 11 illustrates a modification of Fig. 10.

Referring to Fig. 1, the transmitter T may include a circuit-interrupting or modulating device of any type suited to produce a series of signals whose length or duration is determined by or varies as a function of the magnitude of a condition, for example pressure, rate of flow, voltage, current, or of any other condition such as the position of a member movable to effect, or in response to, changes in magnitude of any physical, electrical or chemical condition. For purpose of illustration, the transmitter comprises a cylinder 1 rotated at constant speed, as by motor 2, and whose surface or periphery in part consists of a contact 3 so shaped that the fraction of a revolution for which it engages the co-operating contact 4 depends upon the position of the latter axially of cylinder 1. For many industrial purposes, a speed of the order of thirty revolutions per minute is sufficiently high to follow the changes in magnitude of the condition under measurement.

Contact 4 may be suitably coupled, for example mechanically as exemplified by the broken line 6, to the movable element of instrument 7 responsive to any of the conditions above or hereinafter mentioned. Instrument 7 may for example be operated by a float, Bourdon tube or bimetallic strip or other condition-responsive element. The intermittent engagement of the keying contacts 3 and 4 is utilized to control or produce current impulses at a more or less remote receiving station R; the stations may be connected by conductors 8, 9, both metallic, or at least one comprising earth, in which case the current inter-

rupted by contacts 3, 4 of the transmitter may be supplied by a source at either station and may be unidirectional current, or alternating current of suitably low frequency. Alternately, the transmission of the impulses between the stations may be by current of high frequency, with or without conductors between stations T and R in which case the contacts 3 and 4 may effect keying of the frequency itself or of a superimposed modulation frequency. Particularly when the stations are not conductively connected, each is provided with a suitable local source of current. Rectangles S and S1 generically represent any translating devices or sources of power necessary at the sending and receiving stations for production and reception of current impulses suited to operate relay 10.

In any event, whatever may be the specific nature of the transmitter, the signals, current impulses or intervening time intervals, received at station R are there utilized repeatedly to effect the charging and discharging of a condenser K whose residual charge is intermittently measured, for example thirty times per minute, in determination of the existing magnitude of the condition under measurement. For most applications, the capacity of condenser K may conveniently be of the order of 1 microfarad; the condenser should have a low power factor, negligible leakage, such as afforded by a well-constructed condenser with mica as the dielectric.

In the exemplary system of Fig. 1, the connection of condenser K to suitable charging, discharging, and other circuits hereinafter discussed is controlled by the contact structure of relay 10 which for purposes of explanation is assumed to be energized so long as contacts 3 and 4 of transmitter T are in engagement and de-energized when those contacts are out of engagement with each other. The mechanical arrangement between the movable contact 11 of relay 10 and the armature of the relay is such that when the relay coil is energized the contact 11 is moved from engagement with contact 15 into engagement with contact 14; these contacts remain in engagement until the relay coil is de-energized whereupon contact 11 moves out of engagement with contact 14 and into engagement with contact 15.

Therefore so long as the relay coil is energized, the condenser K is connected through relay contacts 11 and 14 to the battery 16, or other source of direct current, through a resistor 17, having for example a resistance of the order of 1 megohm, which controls the rate at which the condenser is charged. At the end of each period of energization of relay 10, condenser K is connected through contacts 11 and 15 to a discharge or leak circuit including the resistor 18, of the order of 2 megohms, which controls the rate at which displacement current flows from the charged condenser K and therefore the rate at which its voltage falls.

When the relay coil is next energized, the contact 11, in its movement away from contact 15 and toward engagement with contact 14, momentarily engages contact 19 of a measuring circuit including for example the ballistic galvanometer 20 and the potentiometer slidewire 21 preferably supplied with current from the same source 16 utilized for charging of condenser K. If the voltage due to the then remaining charge of condenser K is equal to the voltage drop across the slidewire between its contact 22 and terminal 23, there is no deflection of galvanometer 20 or

equivalent whereas if these voltages are not equal, the galvanometer will deflect in one direction or the other depending upon which voltage is the higher. Contact 22 may be adjusted in accordance with the sense and extent of each deflection to approximate or obtain balance when condenser K is next connected to the measuring circuit.

In each cycle of energization and de-energization of the relay as contact 11, in its movement toward engagement with contact 14, passes beyond the measuring contact 19, it engages contact 24 completing a circuit of negligible resistance completely to discharge condenser K so to ensure the condenser voltage is zero each time the condenser is included in the charging circuit.

Consequently in each revolution or cycle of the transmitter T, the condenser K is charged for a duration of time corresponding with the existing magnitude of the condition under measurement, and for the remainder of the cycle is slowly discharged through the leak resistance 18. The voltage across the condenser at the time of its inclusion in the measuring circuit is therefore a function of the ratio of the charging period to the complete cycle, or of the ratio of the charging period to the leak period. (The times required for movement of contact 11 from contact 14 to contact 15 upon energization of the relay coil and from contact 15 to contact 14 upon de-energization of the relay coil are so short they may be ignored.)

Although the instantaneous voltage across condenser K during charging and discharging thereof through resistors 17 and 18 respectively is an exponential function of time, an essentially linear relation between the duration of the impulses produced by transmitter T and the residual voltage of condenser K may, as hereinafter appears, be established by proper selection of the time constants of the charging and leak-discharge circuits with respect to each other and, in this modification, to the time duration of the cycle of charge and discharge.

Referring to Fig. 2, the curve C represents the voltage across condenser K as a function of time; if for example, the contacts 3 and 4 of transmitter T remain in engagement for 0.6 of a cycle of transmitter T, the voltage on the condenser rises to x , i. e. from zero to approximately 0.4 of the voltage of battery 16, following the law

$$(1) \quad e = E \left(1 - e^{-\frac{t_1}{R_1 C}} \right)$$

Wherein

e = instantaneous condenser voltage

E = charging voltage

t_1 = charging time in seconds

$R_1 C$ = time constant of charging circuit

R_1 = resistance 17 in megohms

C = capacity of condenser K in microfarads

e = base of Napierian logarithms.

In the subsequent interval of de-energization of relay 10, the condenser voltage falls from x to y along a curve D6 also exponential in character. If the charging period per cycle is greater or smaller than 0.6, the voltage rises to greater or less extent along curve C, and falls exponentially from the voltage existent at the end of the charging periods (generally as indicated by the family of curves D1, D9) to an ultimate value uniquely representative of the ratios of the durations of the charging and discharging periods of the cycle.

The residual voltage of the condenser at the end of the leak period is therefore

$$(2) \quad e_r = E \left(1 - e^{-\frac{t_1}{R_2 C}} \right) e^{-\frac{t_2}{R_2 C}}$$

Wherein

e_r = residual voltage of condenser

t_2 = leak discharge time in seconds

$R_2 C$ = time constant of leak circuit

R_2 = resistance 18 in megohms

(Other characters have same significance in Equation 1.)

By proper selection of the resistances of resistors 17 and 18, the residual voltage of condenser K may be made to be very closely proportional to the ratio of the charging time (t_1) to the total time of the cycle ($t_1 + t_2$):

$$\text{i. e. } e_r \propto \frac{t_1}{t_1 + t_2} E$$

For example, if the time constant of the charging circuit is made 10/9 of the total time of a charge-discharge cycle and the time constant of the leak-discharge circuit is made 10/4 of the total time of the cycle, the maximum deviation of the residual voltage from strict proportionality is only about 0.16% of the range; the percent error curve for this example is shown by curve E, Fig. 3. (By shunting the central three-fifths of slidewire 21—assuming the slidewire otherwise affords equal changes in resistance for successive equal movements of contact 22—the error can be still further reduced; when the shunt is of resistance approximately seventy times that of the aforesaid shunted central section, the per cent error is shown by curve F of Fig. 3.)

Other suitable proportions are indicated in the following table:

Ratio of cycle time to—		Maximum error percent full scale	Ratio of slidewire volts to charging volts
Charging time constant	Discharging time constant		
0.5	0.2344	0.048	0.3935
0.6	0.2776	0.070	0.4512
0.8	0.3602	0.125	0.5507
1.0	0.4382	0.195	0.6321
1.2	0.5114	0.274	0.6988
1.5	0.6126	0.416	0.7769
1.9	0.7324	0.635	0.8504
2.3	0.8362	0.812	0.8997

(The ratio of "slidewire volts to charging volts" is determined from ratio of resistance 21 to the sum of resistance 111 and resistance 21.)

Although the foregoing specific results assume the signal cycle time (impulse plus space) is held constant, the error due to variation in cycle time does not so greatly increase because if the cycle time is short the signal time is correspondingly short with consequent charging of the condenser to a sub-normal voltage but because the "off time" is short and the extent of discharge less, the residual charge of the condenser is not greatly less than for normal duration of the cycle time. Similarly if the cycle time becomes longer than normal, the residual charge of the condenser for any given position of contact 4 is less than proportionally increased. The time per cycle may increase or decrease by as much as 10% without increasing the per cent error of the measurements to extent intolerable for many industrial purposes.

When high accuracy is required, notwithstanding

ing possibility of substantial variation in cycle time, recourse may be had to an arrangement such as shown in Fig. 10 and hereinafter fully described of which it is characteristic the residual voltage of condenser K is compared with that of a like condenser charged from a variable voltage during the whole cycle time instead of, as in Fig. 1, being compared with that of a slidewire. It shall be understood either of these methods of comparison may be utilized in the other systems herein described.

In the system shown in Fig. 4, each of the condensers K1, K2, K3 is repeatedly charged and then discharged through a leak resistance, exactly as described in connection with condenser K, Fig. 1. The charge-discharge cycles of the three condensers are so dephased that at all times one or another of them is standing by passively for measurement of its residual charge. Whether or not such measurement is actually made between any particular successive charge-discharge cycles of one of the condensers, depends upon the timing of the switch 25 which need not, and usually does not, operate in synchronism with the keying cylinder 1 of the transmitter.

More particularly one terminal of each of the similar condensers K1, K2 and K3 is connected to the conductor or bus 26 common to the leak circuit including resistance 18 and to the charging circuit including the battery 16; the other terminals of the condensers are connected respectively to contacts 27, 28 and 29 mechanically coupled for movement in unison. Each of these movable contacts successively engages a contact 30 connected to the movable contact 11A of relay 10A, a contact 31 connected through a path of low or negligible resistance to the bus 26, and a contact 32 connected to conductor or bus 33 of the measuring circuit.

The electrical connections to the movable and fixed contacts of the step-by-step switch S1 comprising aforesaid contacts 27—32 are such that while one of the condensers is being slowly charged or slowly and partially discharged, another rapidly and completely discharges, and the third is standing by for connection through switch 25 to the galvanometer or equivalent responsive device.

For each energization of the relay 10A, the contacts 27, 28 and 39 are advanced, as by the pawl and ratchet mechanism 12, 13, to their next position so that (a) the condenser just completely discharged is now connected through contacts 30, 11A, 14 to the charging circuit including resistance 17, (b) the condenser previously included in the measuring circuit is connected through one of contacts 31 to the shorting circuit which completely dissipates its residual charge and (c) the condenser whose leak-discharge is interrupted by movement of relay 11A from contact 15 is connected to a contact 32 for inclusion in the measuring circuit.

The adjustment of slidewire 21 with respect to its contact 22 in response to deflections of galvanometer 20 may be effected automatically as by relay systems of the type generally shown in Patent No. 1,935,732 and Patent No. 2,285,482 generically represented by the block 34, and, if desired, as shown in aforesaid patents, the movements of the adjustable elements of the potentiometer slidewire may be transmitted to an indicating and/or recording element 35 adjustable with respect to a scale 36 and/or a recorder chart 37 driven at substantially constant speed by any suitable source such as the same motor utilized

to effect intermittent operation of switch 25. The scale or recorder chart may be suitably calibrated in units of measurement of the particular condition whose magnitude determines the duration of the impulses transmitted from station T to station R1 at which the relay 10A is located.

The time constants of the charging and discharging circuits are preferably so selected, as above discussed in connection with Figs. 2 and 3, that each of the scales 36 and 37 is linear, i. e., successive equal increments of its length correspond with successive equal increments in the units of measurement.

A preferred form of transmitter keying device TA shown in Fig. 5, similar in some features of construction to apparatus disclosed in co-pending application, Serial No. 434,351, filed March 12, 1942, is suited for attachment to recorders or mechanical relays of the type disclosed in aforesaid Patent 1,935,732. The recorder mechanism M, Fig. 5, includes a slidewire 21T attached to a shaft 39 for adjustment with respect to a relatively fixed contact 22T. The slidewire 21 and galvanometer 20T are included in a primary measuring circuit N suited for measurement and/or control at the transmitter station of the particular condition under measurement; typical examples of network N are disclosed in Letters Patent Nos. 2,124,725, Williams et al.; 2,119,223, Cooper; 2,119,061, Stein et al.; 2,108,294, Doyle et al.; Re. 20,548, Doyle; 2,054,411, Doyle; 2,054,121, Doyle; 1,985,081, Doyle et al.; 1,957,808, Rosecrans; 1,758,494, Behr; 1,751,539, Wunsch.

When the primary measuring circuit is unbalanced, the pointer of the galvanometer 20T deflects in sense corresponding with the unbalance from its central or neutral position. While so deflected a clamping bar or bars (not shown) actuated by a cam (not shown) on the continuously rotating shaft 42 engages the pointer and holds it in deflected position. While the pointer is so held, the feelers 41, 41 are released by a cam, not shown, rotating with shaft 42, for movement toward one another by a biasing spring. One or the other of the feelers, depending upon the sense of deflection of the galvanometer pointer, is effective to swing a driving clutch member 44 through an angle corresponding with the galvanometer's deflection. Subsequently in the cycle of the mechanism, the member 44 under control of a cam, not shown, on shaft 42, is moved into engagement with the driven clutch disc 43. While the clutch members are so engaged, one or the other of the cams 45 engages the driving clutch member 44 and restores it to its original neutral position and since the clutch members 43, 44 during that time are in engagement, the shaft 39 to which the slidewire 21T is attached is moved in direction to restore balance of the measuring network. (For more complete description of the construction and operation of this known portion of the transmitter mechanism, reference is made to aforesaid Squibb patent.)

Upon shaft 39 is attached a disc 46 having a notch 47 which for every different magnitude of the condition has a corresponding angular position. The contact 4A, in general corresponding with contact 4 of transmitter T of Fig. 1, is carried by frame 48 pivotally mounted upon the arms 49 attached to and extending from opposite sides of the gear 50 which is free to rotate upon and with respect to shaft 39. Upon the frame 48 is pivotally mounted the pawl 51 biased as by a spring not shown to the full line position shown

in Fig. 6. When the pawl is in this position, it cooperates with disc 46 to hold the contact 4A from engagement with the contact rings 3A, 3B. When during a revolution of gear 50, the pawl 51 rides into the notch 47 it swings about its pivot 52 to the dotted line position, Fig. 6, and so allows the frame 48 under influence of a biasing spring, not shown, to swing in counter-clockwise direction about its pivot 53 thus to effect engagement of contact 4A with the cooperating contacts 3A, 3B. Later in each revolution of gear 50, the abutment 54 of frame 48 is engaged by the stationary stop 55 and swung in reverse direction about its pivot 53 so to effect separation of contact 4A from contacts 3A and 3B to permit the pawl to return from its dotted to its full line position, Fig. 6. Contact 4A is thus held in circuit-opening position until in the next revolution of the gear 50 the pawl 51 again enters notch 47 of disc 46.

The gear 50 is driven at substantially constant speed from any suitable source of power for example, through gear 56 and shaft 57 suitably connected to the continuously rotating shaft 42 of the mechanical relay mechanism M. From the foregoing it will be understood that for each revolution of gear 50, the ratio of the time for which the contacts 4A, 3A and 3B are in engagement to the time for which these contacts are out of engagement depends upon the angular position of the notch 47, which, as previously stated, corresponds with the magnitude of the condition under measurement. Accordingly at the receiving station, the relay 10, 10A or equivalent of the receiver R is repeatedly energized for periods whose duration is a function of the magnitude of the condition under measurement. These magnitudes may be recorded or indicated at the transmitting station by suitably coupling shaft 39, as by drum 62 and cord 61, to the indicator or marker 58 co-operating with a scale 59 and/or the chart 60. The position of marker or indicating element 58 is reproduced at the receiving station by the indicator or marker 35 under control of the recorder 34; as immediately hereinafter appears however the readings of several transmitters located at the same or different transmitting stations may be integrated at a single receiving station.

Each of the individual receivers R1—RN of Fig. 7, like the receiver of Fig. 4, provides that at all times a condenser is standing by for measurement of its residual charge but in this system, unlike Fig. 4, only two condensers, K4 and K5, are used for each receiver.

The notching relay 10B, Figs. 7 and 8, for controlling the charge and discharge cycles of the condensers comprises a pair of single-pole-double-throw switches S2, S3 whose movable contacts 63 and 64 are connected respectively to the movable contact 11C of relay 10B and to one of the contacts of switch 25 in the measuring circuit.

The cams 80 and 81 for controlling the positions of contacts 63 and 64 are so shaped and so positioned upon shaft 82 that for each one-eighth revolution of shaft 82, i. e., for each energization of relay 10B, each of contacts 63 and 64 moves from one to another of its circuit-closing positions; cams 83, 84 are so shaped and so positioned upon shaft 82 that contacts 69 and 70 are momentarily moved into engagement with contacts 68, 71 respectively in alternate one-eighths of each revolution of shaft 82.

The contact 11C mounted upon the armature-

supporting-member 85 engages contact 14 of the charging circuit so long as relay coil 10B is energized and engages contact 15 of the leak-discharge circuit so long as the coil 10B is de-energized. Contact 11C has the same general purpose as contact 11 of Fig. 1.

When contacts 63, 64 are in the position shown in Fig. 7, and assuming the system has been in operation, condenser K4 is being discharged through the resistances 17 and 18A in series and condenser K5 is standing by with a residual charge in anticipation of closure of switch 25 for measurement of this charge, as in the system of Fig. 1, by comparison against the effective voltage of a slide-wire 21.

When the relay 10B is next energized, contact 64 of switch S3 moves away from engagement with its contact 65M and into engagement with its contact 65R thus to connect condenser K4 at the end of its leak-discharge period to the measuring or standby circuit in readiness for closure of switch 25 of the recorder; at the same time the contact 63 of switch S2 moves out of engagement with its contact 66R to disconnect the condenser K4 from the leak-discharge circuit and by its engagement with contact 66M to include the condenser K5 in the charging circuit including resistance 17, contact 11C and 14 of relay 10B and the source of voltage 16.

Immediately before the charging circuit for condenser K5 is completed, the movable contact 68 of switch S4 momentarily engages its fixed contact 69 completely to discharge condenser K5 in a path of negligible resistance.

Upon de-energization of the relay 10B, the switch members 63 and 64 retain the same positions but the contact 11C of the relay moves out of engagement with contact 14 of the charging circuit and into engagement with contact 15 to include the condenser K5 in the leak-discharge circuit comprising resistances 17 and 18A.

When the relay is next again energized, the contacts 63 and 64 are returned to the positions shown in Fig. 7 and the contact 70 of switch S5 momentarily engages contact 71 completely to discharge condenser K4 before it is again connected through switch S2 to the charging circuit.

From the foregoing it is evident that one or the other of the condensers K4 or K5 is always standing by with a residual charge so that whenever switch 25 of the recorder is closed the system is in condition for measurement of a voltage representative of the magnitude of the condition under measurement at the transmitting station. As in the system of Fig. 4, and in fact in all systems herein illustrated there is no need for operation of the switch 25 in any predetermined timed relation with respect to any mechanism at the transmitting station.

When it is desired to record the summation of the magnitudes of conditions affecting several transmitters T1—TN, there may be provided at the receiving station several receiving units R1—RN, such as immediately above described, each with its own notching relay for controlling the charge and discharge cycles of a pair of condensers and a switch 25 for including in the measuring circuit that one of the pair which is standing by at the time its switch 25 is closed. All switches 25 are closed in unison to mix the residual charges of the condensers then standing by so that the recorder measures a resultant voltage which is proportional to the algebraic sum of the charges.

With the system as thus far described, it would be possible for the switches S2, S3 of any of the different receivers to operate during a measurement (switches 25 closed) and so substitute another condenser for one of the condensers whose charges had been mixed. Such substitution would of course introduce error unless perchance the substituted condenser had the same voltage as the resultant voltage of the parallel condensers under measurement. To avoid this error, control of the relays 10B to 10N by their respective transmitters T1—TN is prevented so long as the switches 25 are closed. To that end, each of the relays is provided with hold-in contacts 72 and 73; the former are all connected to contact 74 of a switch S6 operated concurrently with switches 25 by the recorder mechanism 34. Each auxiliary hold-in contact 73 is connected to one terminal of the corresponding relay coil and to one of the line conductors 8 extending for example to the associated transmitter. The other terminal of each of the relay coils is connected to one terminal of the common source of current 75 whose other terminal is connected to the movable contact 76 of switch S6; each of the other line conductors 9 is connected to contact 77 thereof. Switch S6 is so constructed that movable contact 76 engages contact 77 before moving out of engagement with contact 74 and for movement in reverse direction engages contact 74 before disengagement from contact 77.

When contacts 76 and 77 of switch S6 are in engagement, the operation of each of the receivers R1—RN is exactly as above described with the additional feature that whenever any of the relays 10B—10N is energized its auxiliary contacts 72, 73 are closed. This however is without effect until concurrently with closure of switches 25, the contact 76 of switch S6 is moved into engagement with contact 74 whereupon those relays which were then energized remain energized regardless of closure or separation of their transmitter contacts, and those relays which were then de-energized remain de-energized regardless of operation of the keying contacts 3, 4 or equivalent at their corresponding transmitting stations. When switches 25 are reopened, control of each of the relays 10B—10N is restored to its associated transmitter by concurrent operation of switch S6. The time of closure of switches 25 is very short; of the order of 1% of the cycle time.

If desired, separate sources of current may be provided for each notching relay 10B—10N in which case switch S6 must be duplicated for each additional source.

In recording the resultant voltages of the condensers, it is necessary that the charges on all condensers change by the same amounts (coulombs) for like changes at the transmitter stations; this change in quantity, assuming the measuring range of the several transmitters are different, can be accomplished either by making the capacitances of each pair of condensers proportional to their corresponding measuring range or by using condensers of equal capacitances for all receivers and varying the respective charging voltages of each pair in accordance with their corresponding measuring range.

When, for example as in totalizing tie line loads some of which are "incoming" power and others are "outgoing" power, there is involved the summation of magnitudes of different sign the corresponding residual charges which are mixed by closure of switches 25 must be of proper polarity.

To adapt the system of Fig. 7 to such circumstance, provision may be made, as in Fig. 7A, oppositely to charge the condensers of receivers measuring "incoming" and "outgoing" power respectively.

The return conductor 26 is connected to a point X whose potential is intermediate the potentials of the terminals of the source 16 of charging current. With switch S7 of receiver R3 in full line position, the contacts 14, 14 of relays 10—D and 10—E of the receivers R3, R4 are connected to points Y and Z which are of opposite polarity with respect to point X. Consequently, condensers K4, K5 of receiver R3 are in effect connected by relay contact 14 to a source of charging voltage which is of polarity opposite to that which is connected condensers K4, K5 of receiver R4 under control of relay 10—E. The closure of recorder switches 25 therefore effects mixture of residual charges of opposite sign, the polarity and magnitude of the terminal charge impressed upon the galvanometer depending upon the algebraic summation of the charges.

When the summation of the magnitudes may sometimes be one sign and at other times of opposite sign, the point X should be of potential intermediate the potentials of the ends or terminals of the slidewire 21.

Except for such changes, the operation of Fig. 7A is the same as that of Fig. 7; with switch S7, Fig. 7A, in dotted line position, the condensers are all charged in like sense and Fig. 7A becomes identical in operation with Fig. 7.

The telemetric receiver shown in Fig. 9 is similar to the individual receivers of Fig. 7 in that it utilizes two condensers (K6, K7) whose cycles of charge and discharge are dephased in order that one of them shall always be in readiness for measurement of its charge thus ensuring proper response of the galvanometer irrespective of the timing of the switch 25 with respect to the transmitter. The system is different from that of Fig. 7 in that instead of using a notching relay 10B, or equivalent, there are provided several relays A—10—D—10 electrically interlocked to ensure the desired sequence of their switching operations.

When contacts 85 and 86 of relays A—10 and C—10 respectively are in their closed circuit positions, the condenser K6 is included in the charging circuit comprising resistance 17 and source 16 of charging voltage; similarly when contacts 87 and 88 of relays B—10 and D—10 are respectively in their closed circuit positions, the condenser K7 is included in the charging circuit.

With contacts 85 and 89 of relays A—10 and C—10 in their closed circuit positions, the condenser K6 is included in the leak discharge circuit including resistance 18; similarly with contacts 87 and 90 of relays B—10 and D—10 in their closed circuit position, the condenser K7 is included in the leak discharge circuit.

With contact 91 of relay A—10 in closed circuit position, the condenser K6 is standing by for measurement of its residual charge when recorder switch 25 momentarily closes; with contact 92 of relay B—10 in closed circuit position, condenser K7 is standing by for measurement of its residual charge upon closure of switch 25.

With contacts 85, 93 and 94 of relays A—10, B—10 and C—10 respectively in closed circuit position, condenser K6 is short-circuited for complete dissipation of its residual charge before it is again connected to the charging circuit; sim-

ilarly with contacts 87, 95 and 96 of relays B—10, A—10, and D—10 in their closed circuit position, condenser K7 is completely discharged in readiness for reconnection to the charging circuit.

The circuit for energization of relay A—10 is completed only when the contacts 97 and 98 of relays B—10 and C—10 are closed; similarly relay B—10 is energized only when contacts 99 and 100 of relays A—10 and D—10 are closed. Neither of these circuits includes the contacts 3, 4 of the transmitter.

Assuming the keying contacts 3, 4, or equivalent, are closed, the relay C—10 may be energized through either of two circuits one including the closed contacts 101, 102 and 103 of relays A—10, B—10 and D—10 and the other including contacts 103, 104 of relays D—10 and C—10; again assuming keying contacts 3, 4 or equivalent are closed, the relay D—10 may be energized through either of two circuits one including contacts 105, 106, and 107 of relays A—10, B—10 and C—10 and the other including contacts 107 and 108 of relays C—10 and D—10.

Assuming the relay contacts are in the positions shown in Fig. 9, relay A—10 is energized and relays B—10, C—10 and D—10 are de-energized; condenser K6 is standing by for measurement of its residual charge; condenser K7 is slowly discharging through resistance 18. Upon closure of contacts 3C, 4C of signal relay E—10 in response to separation or closure of the corresponding transmitter contacts, relay C—10 is energized whereupon contact 98 thereof interrupts current to the operating winding of relay A—10 and contact 104 completes a seal-in circuit for relay C—10. The resulting movements of contacts 91 and 85 of relay A—10 effect removal of condenser K6 from the measuring circuit and effect its inclusion in the short-circuit path including contact 94 of energized relay C—10 and contact 93 of the de-energized relay B—10. The de-energization of relay A—10, by closure of its contact 99, effects energization of relay B—10; in consequence contact 93 of B—10 removes condenser K6 from the short-circuit path and permits charging of condenser K6 now in the circuit comprising contact 85 of de-energized relay A—10, contact 86 of energized relay C—10, resistance 17 and source 16.

The aforesaid energization of relay B—10 also effects movement of its contacts 87 and 92 to remove condenser K7 from the leak discharge circuit including resistance 18 and to transfer it into the measuring circuit comprising switch 25.

The foregoing operations of relays C—10, A—10, and B—10 all occur within a very brief time; insofar as any effect upon the measurements are concerned, the transition of condenser K6 from "stand-by" to "charge" and of condenser K7 from "discharge" to "stand-by" is instantaneous. So long as contacts 3C, 4C remain closed, relays A—10 and D—10 remain de-energized and relays B—10 and C—10 remain energized.

When impulse or signal relay E—10 is de-energized by separation of the contacts 3, 4 of transmitter T1, contacts 3C, 4C of the relay E—10 separate to de-energize relay C—10 whereupon movement of contacts 86 and 89 of relay C—10 transfer condenser K6 from the charging circuit including resistance 17 and source 16 to the leak-discharge circuit including resistance 18. Condenser K7 remains in the stand-by or measuring circuit. So long as contacts 3C, 4C remain open, relays A—10, C—10 and D—10 re-

main de-energized and relay B-10 remains energized.

When the signal relay E-10 is next re-energized, relay D-10 is energized through the circuit including contacts 3C, 4C of relay E-10, contact 105 of relay A-10, contact 106 of relay B-10 and contact 107 of relay C-10. The resulting opening of contact 100 of relay D-10 effects de-energization of relay B-10 whose contacts 87 and 92 thereupon move to disconnect condenser K-7 from the stand-by circuit and to include it in the shorting circuit comprising contact 87 of relay B-10, 95 of A-10, and contact 96 of relay D-10.

The de-energization of relay B-10 effects energization of relay A-10 through the circuit including contacts 97 and 98 of the de-energized relays B-10 and C-10 respectively. The resulting movement of contacts 85 and 91 of relay A-10 disconnects condenser K6 from the leak-discharge circuit and connects it to the measuring circuit including switch 25. Condenser K7 is included in the charging circuit through contacts 87 and 88 of relays B-10 and D-10 respectively.

All of these operations of relays D-10 and B-10 and A-10 occur in rapid sequence and are in effect instantaneous insofar as any effect upon the measurements are concerned. Until contacts 3C, 4C of relay E-10 separate upon termination of the signal impulse, relays A-10 and D-10 remain energized and relays B-10 and C-10 remain de-energized.

When contacts 3C, 4C separate, relay D-10 is deenergized to transfer, by movement of its contacts 88 and 90, condenser K7 from the charging circuit to the leak-discharge circuit.

The foregoing sequence of relay operations is repeated for each subsequent group of two signal cycles.

Should the supply of current 110 for the operating coils of relays A-10 to D-10 be interrupted or fail, it is not necessary manually to re-set the relays in accordance with any schedule or plan to insure operation of the relays in proper sequence. Upon resumption of supply of current, both relays A-10 and B-10 are energized but one or the other acts the more rapidly, locks out the other, and establishes a set of contact-positions of the remaining relays in dependence upon the position of contacts 3C, 4C of the impulse relay. (Following the first cycle after resumption of supply of power, the operation of the system is as above described; at the beginning of the first cycle, if the interruption is prolonged, there is no residual charge on either of the condensers of each receiver.)

As in the systems of Figs. 7 and 7A, the charges of several condensers of different receivers may be mixed and the resultant charge impressed, by closure of switches 25, upon a common measuring circuit. As in preceding systems, the switch or switches 25 need not operate in any particular timed relation with respect to operating mechanism of the transmitters.

In Fig. 9, as in preceding modifications, the time constants of the charge and leak-discharge circuits are so selected with respect to each other and to the time per cycle that the residual charge is a linear function of the charging time (or leak discharge time). So long as the cycles are maintained of substantially constant length, the error due to curvature of the charge and discharge curves, Fig. 2, is reasonably small.

The energization and de-energization of relay E-10, Fig. 9, similar in construction to relay B-10 of Fig. 8, may be controlled from a remote transmitter by any of the methods hereinbefore mentioned.

When extremely high accuracy is required and/or when the cycle time may vary widely, these systems may be modified in accordance with Fig. 10, in which the residual voltage of the measuring condenser (K8 or K9) is compared, not with the setting of a potentiometer slidewire supplied from a source of fixed voltage, but with the voltage of a condenser (C1 or C2) whose charge is a function of the total time of the cycle and so varies with variation in duration of the cycle. In other respects, the system of Fig. 10 is generally similar to these previously described.

The charge on condenser K8 (or K9) at the end of a charge-leak discharge cycle is

$$(3) \quad e_r C = EC \left(1 - e^{-\frac{t_1}{R_1 C}} \right) e^{-\frac{t_2}{R_2 C}}$$

(Characters have same significance as in Equations 1 and 2.)

The charge on condensers C1 or (C2) at the end of the same cycle is

$$(4) \quad e_s C = m EC \left(1 - e^{-\frac{-(t_1+t_2)}{R_1 C}} \right)$$

Where e_s = final condenser voltage and m = fraction of total slidewire voltage applied to C1 or C2.

At balance $e_r C = e_s C$ and therefore

$$(5) \quad m = \frac{\left(1 - e^{-\frac{t_1}{R_1 C}} \right) e^{-\frac{t_2}{R_2 C}}}{1 - e^{-\frac{t_1+t_2}{R_1 C}}}$$

With contact G-11 in the position shown in Fig. 10, condenser K9 is charged through resistance 17 from the source of voltage comprising end-coil resistor 111 of the potentiometer circuit. Upon de-energization of relay G-10, its contact G-11 moves into engagement with contact G-15 and condenser K9 thereupon relatively slowly discharges through resistance 17 and leak resistance 18 until relay G-10 is again energized.

Throughout both the charging and leak-discharge periods of condenser K9, the condenser C2 is connected through contacts 112, 113 to its charging circuit comprising resistor 17C and that portion of potentiometer slidewire 21 determined by the setting of slidewire contact 22.

When relay G-10 is again energized, contact 112 is moved away from contact 113 and into engagement with contact 114 to transfer condenser C2 from its charging circuit to the stand-by circuit into which condenser K9 is substantially concurrently transferred by movement of contact 115 from engagement with contact 116 into engagement with contact 117. The two condenser charges, one a function of the ratio of charging time to leak-discharge time and the other a function of the sum of those periods, are mixed and the resultant voltage impressed upon the measuring circuit including galvanometer 20 when switch 25 of the recorder thereafter closes.

Concurrently with these movements of switch members 112, 115, the contact member 118 moves into engagement with contact 119 to include the other measuring condenser K8 in the charging

circuit including resistance 17 and simultaneously the contact 120 moves into engagement with contact 121 to connect standard or comparison condenser C1 in the charging circuit including resistor 17C and slidewire 21.

At the end of the current impulse, relay G—10 is de-energized whereupon its contact G—11 moves from contact G—14 and into engagement with contact G—15 so terminating the charging period of condenser K8 and initiating its leak-discharge period which ends to complete the cycle of condenser K8 when the relay G—10 is next re-energized. Until such de-energization, the voltage of the comparison condenser C1, is gradually increased so that the magnitude thereof at the end of the cycle is a function of the duration of the cycle.

When relay G—10 is next re-energized, the movable contacts 118 and 120 are moved into engagement with their associated fixed contacts 122, 123 to mix the charges of condensers C1 and K8 in readiness for the next closure of recorder switch 25. This completes two charge-leak discharge cycles, one for each of condensers K8, K9, or one relay cycle; all subsequent operations are repetitions of the same sequence.

For simplicity, all of condensers C1, C2, K8 and K9 are of equal capacity and the two charging resistors 17, 17C are of equal magnitude of resistance; more generally, considering either pair of condensers, C1, K8 or C2, K9, the time constants of the charging circuits should be equal and the product of the capacity of each condenser and its maximum available charging voltage is equal to the corresponding product of the other capacity and its maximum available charging voltage.

For the step-by-step or notching relay of Fig. 10 may be substituted a group of interlocked sequence relays AA—10-DD—10, Fig. 11, corresponding with relays A—10-D—10 of Fig. 10. The disposition and interconnections of the three lower sets of contacts of these relays which control their sequential operation are the same as in Fig. 10; these contacts are therefore identified by the same characters as in Fig. 10 and description of the relay operations is not repeated.

The charging circuit of condenser K8 is completed when contacts 125 and 126 of relays AA—10 and CC—10 are closed; the charging circuit of condenser K9 is completed when contacts 127 and 128 of relays BB—10 and DD—10 are closed. Both charging circuits include the resistor 17 and the source 111 of charging voltage.

The leak discharge circuit of condenser K8 is completed when contacts 125 and 129 of relays AA—10 and CC—10 are closed; the leak discharge circuit of condenser K9 is completed when contacts 127 and 130 of relays BB—10 and DD—10 are closed. Both leak discharge circuits include the resistance 18.

The charging circuit for the standard or comparison condenser C1 is completed so long as contacts 131 and 132 of relays AA—10 and DD—10 are closed; similarly, the charging circuit of comparison condenser C2 is completed so long as contacts 133 and 134 of relays BB—10 and CC—10 are closed. Both charging circuits include resistance 17C.

When contacts 135 and 136 of relay AA—10 are closed, condensers K8 and C1 are connected for mixture of their charges and are included in the stand-by circuit for measurement of the re-

sultant residual charge upon closure of recorder switch 25; likewise, when contacts 137 and 138 of relay BB—10 are closed, condensers K9 and C2 are connected for mixture of their charges and are included in the stand-by circuit for measurement of the resultant residual voltage upon closure of switch 25.

The sequential operation of relays AA—10-DD—10 in response to successive energization of relay E—10 effects essentially the same de-phased cycles of charge, leak-discharge, stand-by and measurement described in connection with Fig. 10.

In selecting the magnitudes of C1, C2, K8, K9, 17, 17C and 18 to obtain minimum deviation from a mean value at any point in the measuring range for large variation in cycle times, a cycle time about 25% greater than the maximum cycle time expected is used as the cycle time of the preceding tables. For example, assuming the cycle time varies from about .144 second to 1.152 seconds, a "normal" cycle time of 1.44 seconds is selected; assuming a charging time constant of 2 seconds the corresponding discharge time constant should be about 4.4 seconds; the resulting maximum deviation from the mean at any point in the range of measurement is not greater than about .12% of the range.

In all modifications herein disclosed, the condensers are each charged from a source common to slidewire or other standard of voltage so avoiding need more or less frequently to readjust the slidewire current to ensure accurate measurements; the calibration of the slidewire scale or equivalent recorder chart depends only upon the constants of passive circuit elements including resistances 17, 18, 111, 21 and condensers K to K9.

It shall be understood that in all modifications, the signal for initiating charging of a condenser at a receiver may be considered to begin either upon engagement or upon disengagement of contacts 3, 4 or equivalent at a transmitter; either the current impulses or the intervening intervals may be utilized as the signal depending upon the selected type of transmitter and receiver relay.

In the modifications shown in Figs. 1, 4, 7, 7A and 9, the resultant or residual voltage instead of being measured potentiometrically may be measured by direct application to a ballistic galvanometer, as in Fig. 10 of U. S. Letters Patent 2,285,482, Wunsch.

What I claim is:

1. A method of measurement which comprises charging and discharging a capacitative reactance in complementary intervals of time, complementarily varying the lengths of said intervals in accordance with changes in magnitude of a condition to vary the magnitude of the residual charge of the reactance, and measuring the residual charge of the reactance in determination of the magnitude of said condition.

2. A method of measurement which comprises repeatedly charging and discharging a capacitative reactance in complementary intervals of successive cycles, varying the length of the charging intervals in accordance with successive different magnitudes of a condition to vary the magnitudes of the residual charges of the reactance, and controlling the rates of charge and discharge of the reactance to establish substantial proportionality of the successive magnitudes of the residual charges of the reactance to the durations of successive charging intervals, and measuring the residual charges of the reactance in determination of aforesaid magnitudes of said condition.

3. A method of measurement which comprises producing impulses of duration varying as a function of the magnitude of a condition, repeatedly charging and discharging a capacitative reactance to extents respectively corresponding with the durations of the impulses and intervening intervals, and measuring the residual charges of the reactance in determination of the magnitude of said condition.

4. A method of measuring which comprises producing impulses of duration varying as a function of the magnitude of a condition, repeatedly charging and discharging a capacitative reactance for periods respectively corresponding with the durations of the impulses and the intervening intervals, fixing the rates of charge and discharge of the reactance to establish substantial proportionality of the successive residual charges of the reactance to the durations of the successive impulses, and measuring the residual charges of the reactance in determination of the magnitude of said condition.

5. A method of measurement which comprises repeatedly charging and discharging a condenser in complementary intervals of substantially equal successive cycles, complementarily varying the lengths of said intervals in accordance with successive different magnitudes of a condition to vary the residual voltages of the condenser, and intermittently opposing the residual voltage to a standard voltage in determination of aforesaid magnitudes of said condition.

6. A method of measurement which comprises repeatedly charging and discharging a condenser in complementary intervals of successive time cycles, complementarily varying the lengths of said intervals in accordance with successive different magnitudes of a condition to vary the residual voltage of the condenser, and intermittently opposing the residual voltage to a voltage which is a function of the condenser-charging voltage.

7. A method of measurement which comprises repeatedly charging and discharging a condenser in complementary intervals of successive cycles which may differ substantially in duration, complementarily varying the lengths of said intervals in accordance with successive different magnitudes of a condition to vary the residual charges of the condenser, charging a second condenser to extent varying as a function of the duration of aforesaid cycles, and comparing the residual charges of the first condenser with the charges of the second condenser to determine aforesaid magnitudes of said condition.

8. A method of measurement which comprises repeatedly charging and discharging two or more capacitative reactances each in complementary intervals of non-coincident cycles, varying the length of the charging intervals in accordance with the successive different magnitudes of a condition, and measuring the residual charges of the reactance in determination of aforesaid magnitudes of said condition.

9. A method of measurement which comprises repeatedly charging two or more condensers each in complementary intervals of successive cycles which may differ in phase with respect to the cycles during which another of the condensers is charged and discharged, varying the length of the charging intervals of the condensers each in accordance with successive different magnitudes of a condition, and measuring the resultant of the residual charges of the condensers in determination of the summation of co-existing magnitudes of the conditions.

10. A system for measuring the magnitudes of a condition comprising a capacitative reactance, a charging circuit, a leak circuit, a measuring circuit, a cyclic means for periodically including said reactance in said charging circuit for a time substantially corresponding with the existing magnitude of said condition, then transferring it to said leak circuit for substantially the remainder of a cycle, and transferring it from said leak circuit to said measuring circuit to determine aforesaid magnitude of said condition.

11. A system for measuring the magnitudes of a condition comprising a condenser, a charging circuit, a leak circuit, a potentiometer circuit including a slidewire, cyclic means for periodically including said condenser in said charging circuit for a time substantially corresponding with the existing magnitude of said condition, then transferring it to said leak circuit for substantially the remainder of the cycle, and transferring it from said leak circuit to said potentiometer circuit for opposition of its residual voltage to the effective slidewire voltage, and means responsive to unbalance of said voltages to determine successive magnitudes of said condition.

12. A measuring system comprising a condenser, a charging circuit, a leak discharge circuit, a measuring circuit, and means for repeatedly including said condenser in said charge circuit for a time proportional to the existing magnitude of a condition, transferring it to said leak discharge circuit for a complementary time interval, and then transferring it from said leak discharge circuit to said measuring circuit to determine aforesaid magnitude of the condition.

13. A measuring system comprising a condenser, a charging circuit, a leak discharge circuit, a measuring circuit including a slidewire traversed by current of substantially constant magnitude, and means for repeating the sequence of inclusion of said condenser in said charging circuit for a time proportional to the existing magnitude of a condition under measurement, of transfer of the condenser to said leak discharge circuit for a complementary period of time, and of balancing the residual voltage of the condenser against a voltage derived from said slidewire in determination of aforesaid magnitude of said condition.

14. A measuring system comprising condensers, means for charging one of said condensers at controlled rate for a time substantially proportional to the existing magnitude of a condition to be measured and for discharging it at controlled rate for a complementary period of time, means for charging another of said condensers at controlled rate throughout aforesaid charge and discharge of said one of said condensers, means for mixing the resulting charges of the condensers, and means including means responsive to their residual voltage after aforesaid mixture of charges to determine aforesaid magnitude of the condition.

15. A measuring system comprising a condenser, a charging circuit, a leak discharge circuit, cyclic means for including said condenser successively in said circuits for complementary times one of which is directly proportional to the magnitude of a condition under measurement, and means for measuring the residual voltage of the condenser, the time constants of said circuits bearing such relation to the cycle time and to each other the magnitude of said residual voltage is essentially a linear function of the magnitude of said condition notwithstanding

ing the voltage of said condenser increases exponentially during charge and decreases exponentially during discharge.

16. A measuring system comprising a condenser, a charging circuit, a leak circuit, a potentiometer circuit including a slidewire, cyclic means for including said condenser in said charging circuit for a time substantially corresponding with the existing magnitude of a condition to be measured, then transferring it to said leak circuit for substantially the remainder of the cycle, and transferring it from said leak circuit to said potentiometer circuit for opposition of its residual voltage to the effective slidewire voltage, and means responsive to unbalance of said voltages for effecting adjustment of said slidewire in sense to establish balance of said voltages in determination of aforesaid magnitude of the condition.

17. A measuring system comprising a charging circuit, a leak circuit, a measuring circuit, a capacitive reactance, means for producing a succession of signals of duration varying as a function of the magnitude of a condition to be measured, and means responsive to said signals for effecting inclusion of said reactance successively in said charging circuit, said leak circuit and said measuring circuit in determination of the magnitude of the condition.

18. A measuring system comprising cyclic means for producing a succession of signals of duration varying as a function of the magnitude of a condition, a capacitive reactance, a charging circuit whose time constant is within the range of about 200% to 40% of the cycle time of said means, a leak circuit whose time constant is within the range of about 400% to 100% of

the cycle time, a measuring circuit, and means responsive to said signals for sequentially including said reactance in said charging, leak and measuring circuits respectively.

19. A system for measuring a magnitude of a condition comprising a condenser, a charging circuit including a voltage source, a leak circuit, a potentiometer circuit including a slidewire supplied with current from said source, cyclic means for periodically including said condenser in said charging circuit for a time substantially corresponding with the existing magnitude of said condition, then transferring it to said leak circuit for substantially the remainder of the cycle, and then transferring it to said potentiometer circuit for opposition of its residual voltage to a fraction of the voltage of said source determined by the slidewire setting, and means including means responsive to flow of current between said condenser and slidewire during aforesaid opposition for determination of aforesaid magnitude of said condition.

20. A system comprising at least two condensers, circuits in which said condensers respectively may be connected, means for charging said condensers, switching means repeatedly sequentially to connect said condensers to said circuits in dephased cycles and including contact structure constructed and operated to ensure at all times at least one of said condensers is standing-by with a residual charge, a measuring network, and means operable at any time with respect to said switching means for connecting said measuring network to a condenser then standing-by.

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