

March 16, 1937.

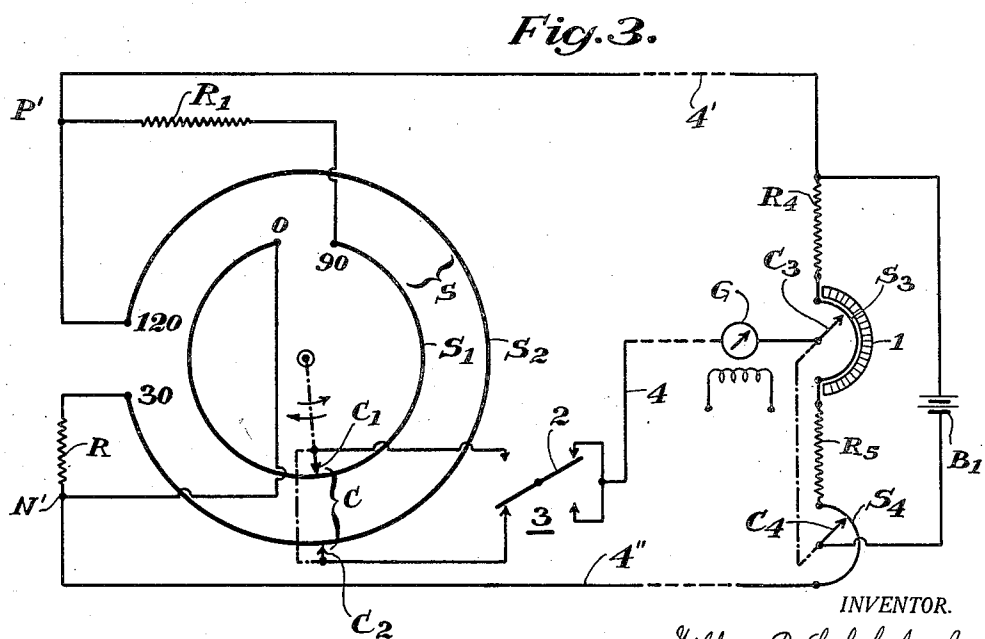
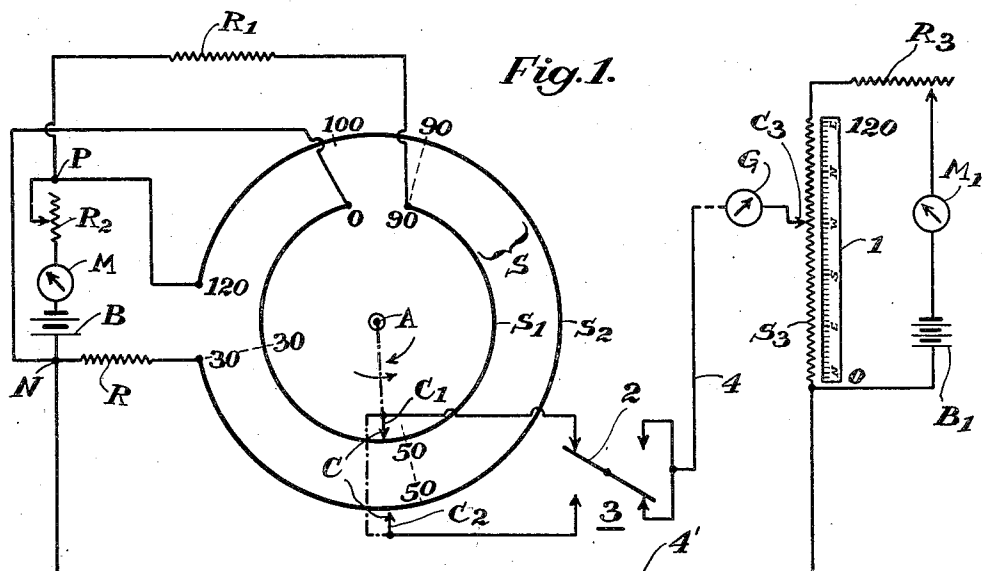
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2,073,948

ELECTRICAL TELEMETRY

Filed June 14, 1933

7 Sheets-Sheet 1



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ELECTRICAL TELEMETRY

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Fig. 5.

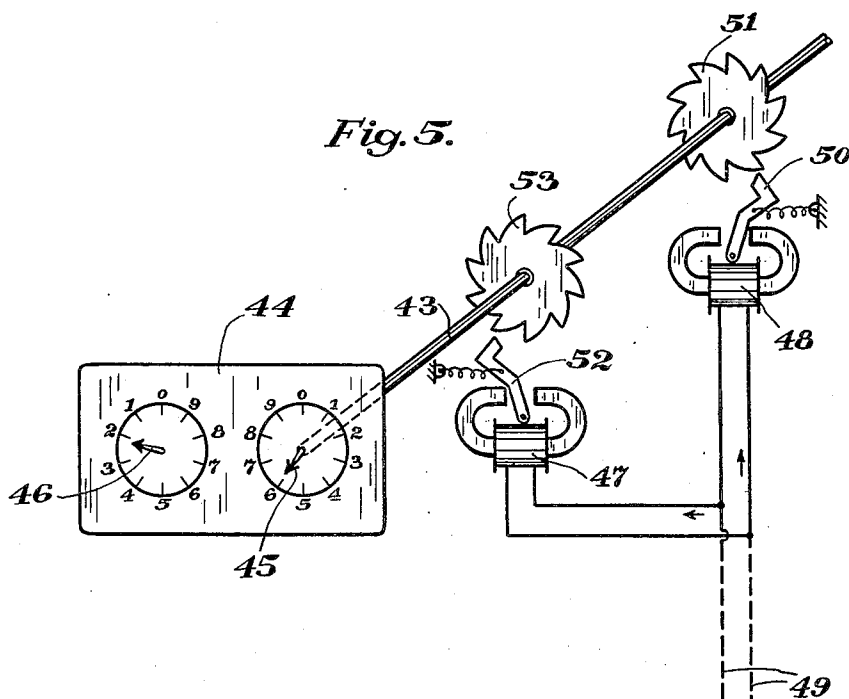
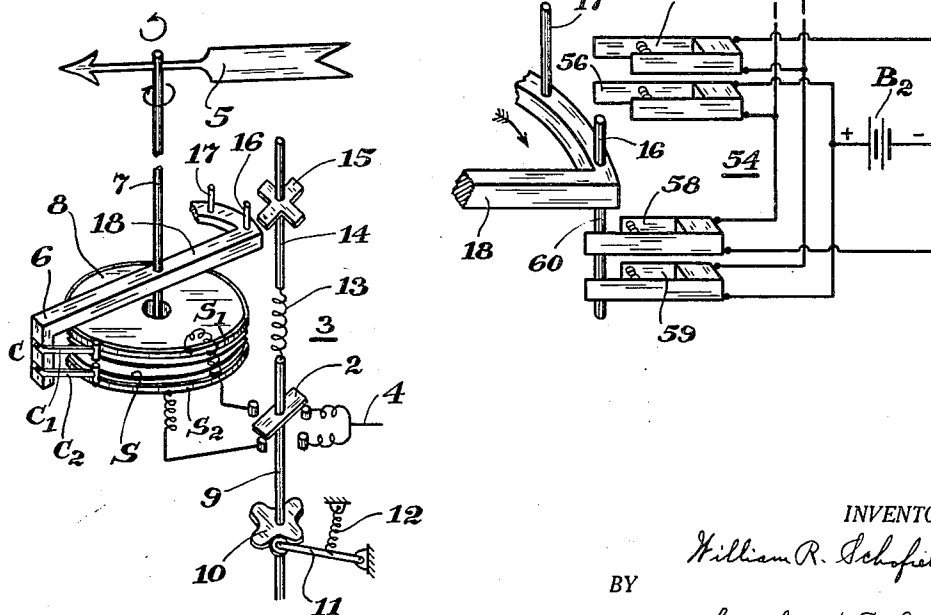


Fig. 2.



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7 Sheets-Sheet 3

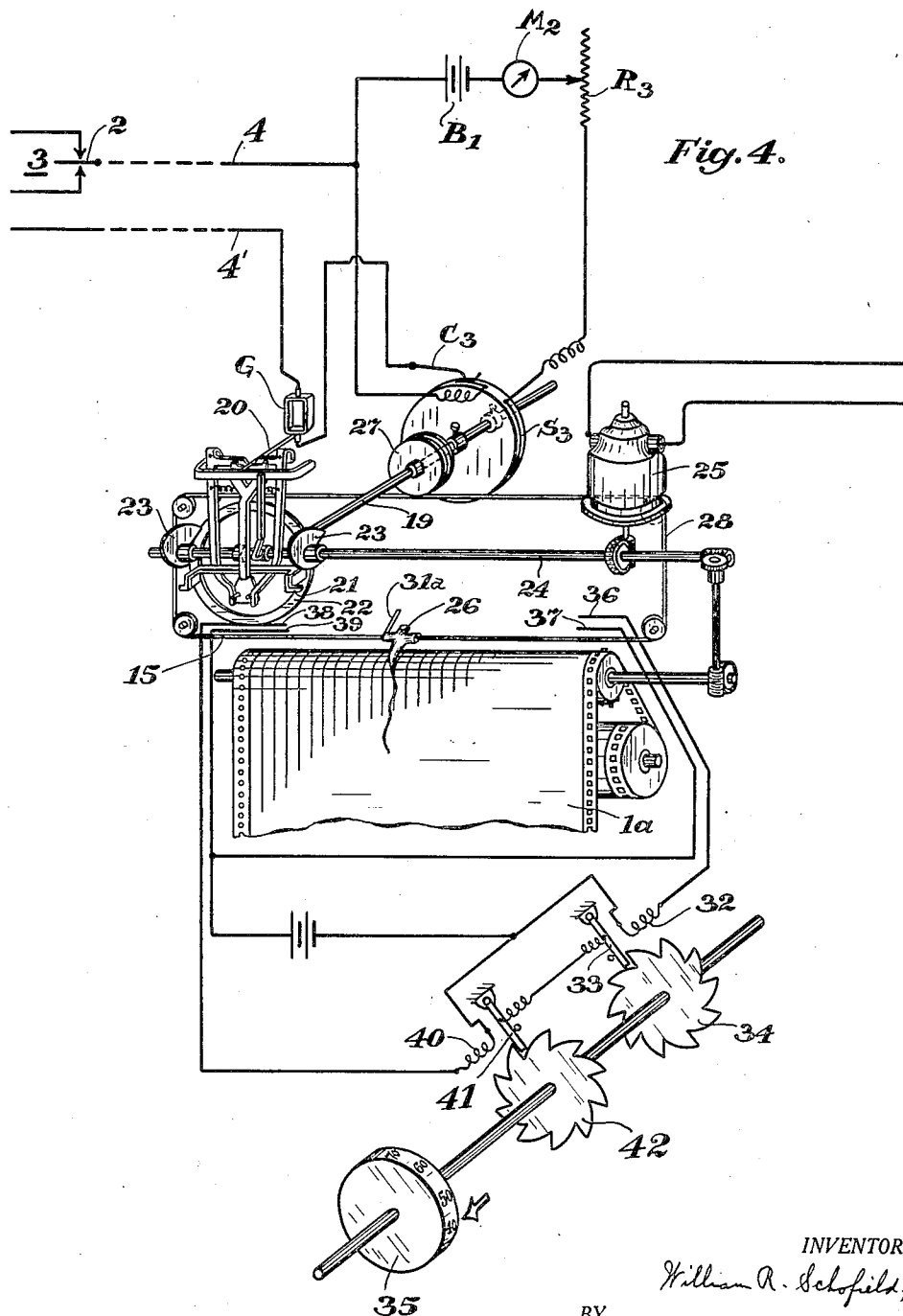


Fig. 4.

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ELECTRICAL TELEMETRY

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Fig. 10.

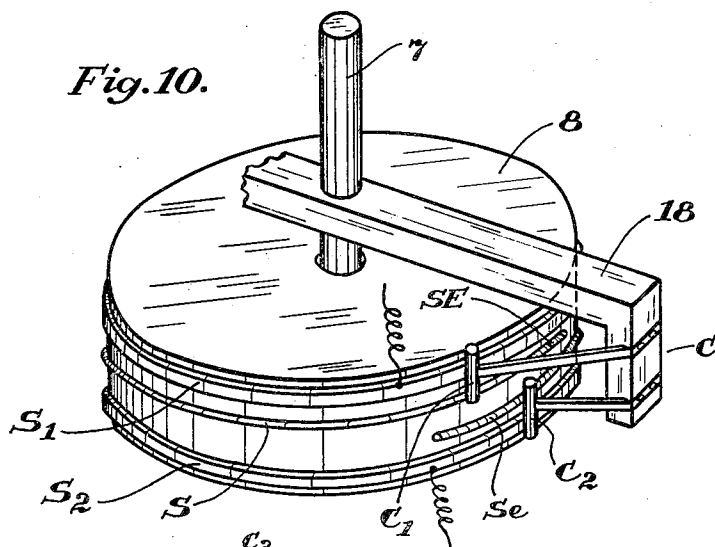


Fig. 9.

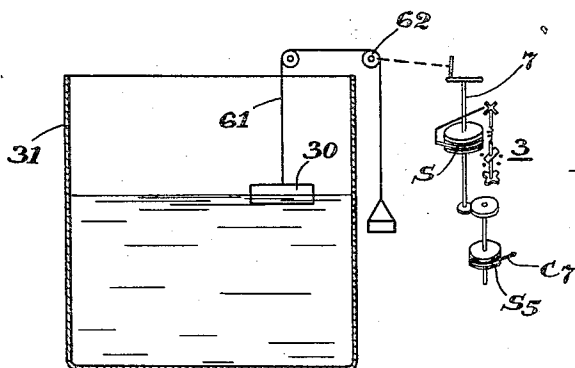
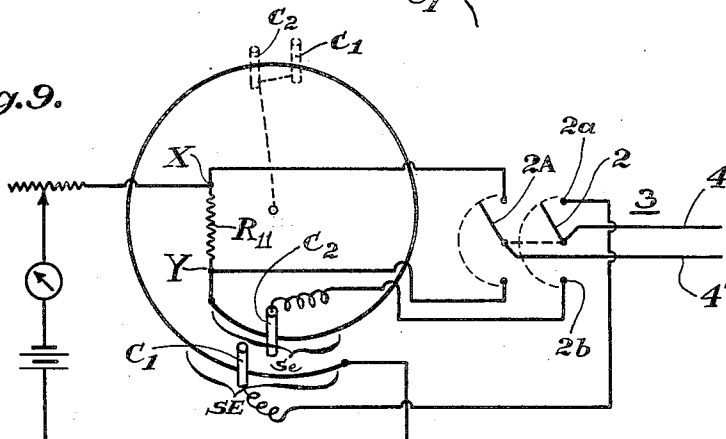


Fig. 6.

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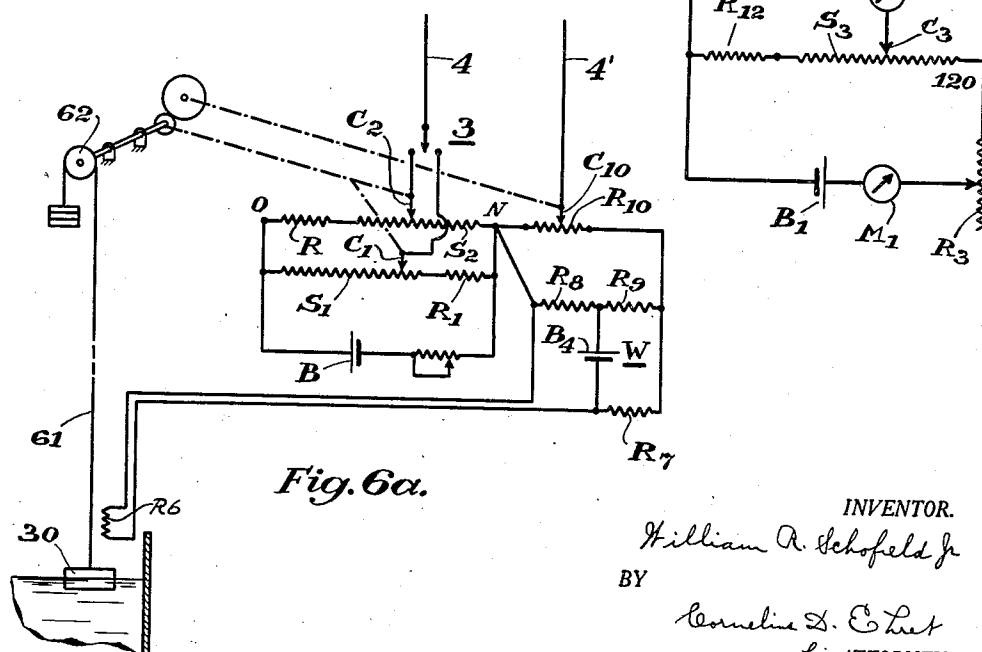
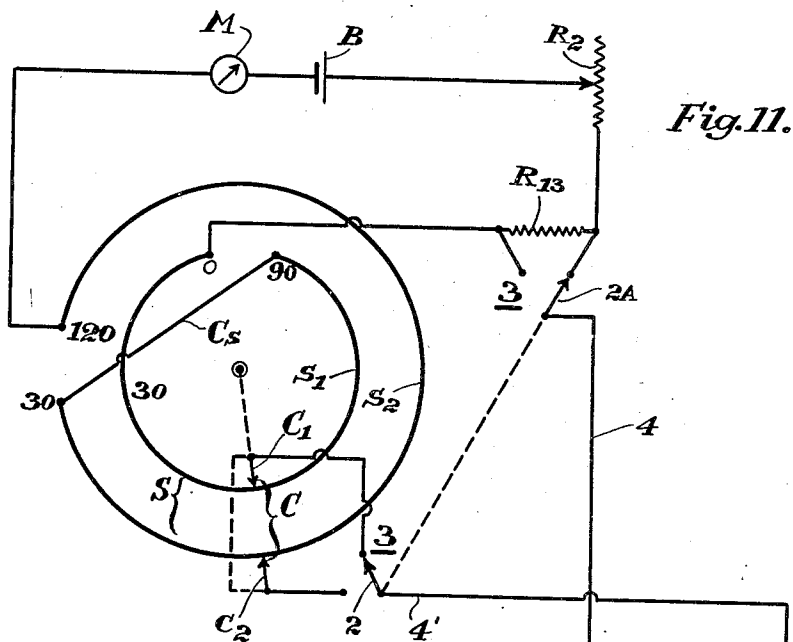
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ELECTRICAL TELEMETRY

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7 Sheets-Sheet 5



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7 Sheets-Sheet 6

Fig. 1.

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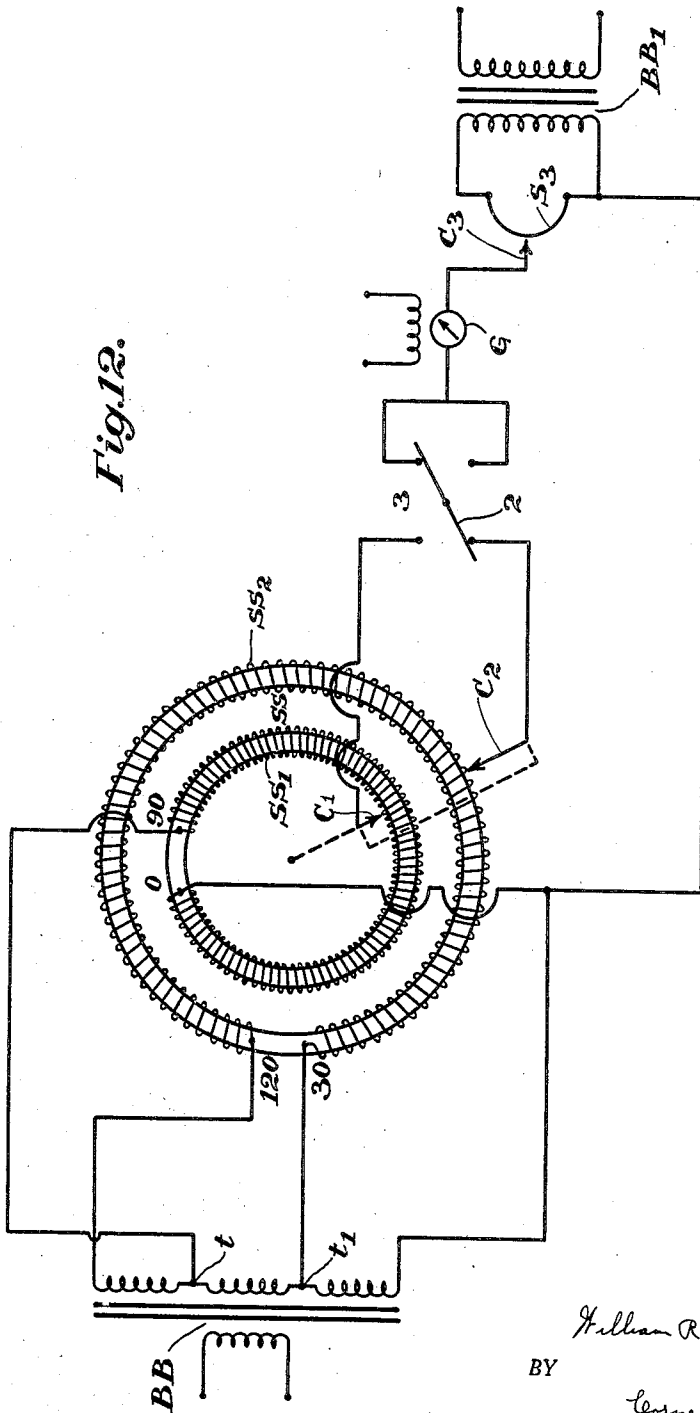
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Fig. 12.



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UNITED STATES PATENT OFFICE

2,073,948

ELECTRICAL TELEMETRY

William R. Schofield, Jr., Philadelphia, Pa., assignor to Leeds & Northrup Company, Philadelphia, Pa., a corporation of Pennsylvania

Application June 14, 1933, Serial No. 675,705

18 Claims. (Cl. 177—351)

My invention relates to electrical systems for determining or recording at a receiving station, the magnitude or changes of a condition at a more or less remote transmitting station.

5 In systems of this character, it has not heretofore been possible to ascertain all positions of the transmitting element when that element was capable of at least 360° of movement, or more specifically, of making unlimited number of revolutions in one or both directions.

10 In accordance with my invention, the transmitting slide-wire is greater than 360° in extent, and preferably is comprised of sections less than 360° in extent with their ends staggered or overlapping, and the cooperating contact structure is divided into elements selectively connected to the transmission line between stations by switching mechanism which is preferably controlled by the transmitting element.

15 My invention also resides in the features of construction, combination and arrangement hereinafter described and claimed.

For an understanding of my invention and for illustration of various modifications thereof, reference is to be had to the accompanying drawings in which:

Fig. 1 illustrates diagrammatically an electrical measuring system.

Fig. 2, in perspective, illustrates apparatus adapted to be included in the system of Fig. 1.

Fig. 3 diagrammatically illustrates a Wheatstone bridge system utilizing the invention.

Fig. 4, partly in perspective, illustrates indicating and recording mechanism.

Fig. 5 diagrammatically illustrates another type of indicator.

Fig. 6 diagrammatically illustrates apparatus for transmitting indication of a liquid level.

Fig. 6a illustrates a modification affording temperature compensation.

Fig. 7 illustrates a system utilizing the invention for determination of integrated and fractional revolutions.

Fig. 8 illustrates another modification for recording integrated and fractional revolutions and which provide for automatic recalibration of the system.

Fig. 9 illustrates diagrammatically a system utilizing a single section slide wire.

Fig. 10 illustrates in perspective the slide wire and contact structure of Fig. 9.

Fig. 11 is a modification utilizing overlapping slide wire sections in series.

Fig. 12 is a modification utilizing an inductive slide-wire.

Referring to Fig. 1 the transmitting slide wire S comprises two sections S1, S2, each less than 360° in extent, but staggered so that each section bridges or overlaps the discontinuity or gap of the other. By way of example, the slide wire sections may each enclose 90% of a circle and may be displaced 30%, as shown by Fig. 1. The cooperating contact structure C consists of the contact elements C1 and C2 which engage the slide wires S1, S2 respectively. The resistance R connected between the low potential end of the section S2 and the point N of the network, and the resistance R1 connected between the high potential end of the slide-wire section S1 and the point P of the network are of such value that from 30 to 90, the contact elements C1, C2 are simultaneously at the same potential.

The change of magnitude of the condition to be measured, for example temperature, wind direction, pressure, etc., effects in any known manner relative movement between the slide wire and its contact structure, i. e., the slide wire may move with respect to the contact structure C1, C2 or vice versa. In either case, the range of relative rotation may be more than one revolution, or in fact an unlimited number of revolutions in some instances. Assuming for purposes of explanation that the contacts are movable with respect to the slide wire, the two contact elements C1, C2 are movable as a unit about the axis A, the contacts remaining in fixed position relative to each other.

Between the points P and N are connected a suitable source of current B and a resistance R2 adjustable to regulate the current flowing through the slide wire as indicated by meter M so that it corresponds to the value for which the slide wire is calibrated. The receiving station may comprise a receiving slide wire S3 connected across a suitable source of current B1, in series with a resistance R3 for adjusting the slide wire current as indicated by the meter M1 to the value for which the slide wire scale 1 is calibrated.

The operation of the system is as follows:

Assume that the magnitude of temperature, pressure or other condition under measurement is such that the contact C1 engages slide-wire section S1 at zero, and is connected by contact 2 of the double throw switch 3 to conductor 4 of the transmission line 4, 4' which extends between the transmitting and receiving stations. For this position of the contact structure of the transmitting slide wire, the galvanometer G gives zero deflection indicating balance of the

system when the contact C3 is adjusted to zero of the scale 1 of the receiving slide wire.

Assuming that the contact structure is now rotated in counter-clockwise direction because of change of the condition under measurement, the potential of contact C1 increases, and to rebalance the system so that the galvanometer G gives null indication, contact C3 is moved upwardly, as shown in Fig. 1, the scale 1 indicating the new magnitude of the measured condition.

It is apparent that if the contact 2 of the switch 3 remains in the position indicated in Fig. 1, that when contact C1 is moved beyond point 90 of slide wire S1 any position of contact C3 of the receiving slide wire would indicate a false balance due to an opening in the galvanometer circuit G. Therefore, suitably before the contact C1 reaches this point, say, for example, at about 85% of a revolution from the zero point, switch 3 is operated, manually at the receiving station, or preferably automatically at the transmitting station as hereinafter described, to disconnect the conductor 4 from contact C1 and to connect it to the contact C2. As the two contacts C1 and C2 at this time are at points of the same potential on the different slide wires S1 and S2, the transition from one to the other effected by operation of switch 3 does not require change in position of the contact C3 for balance, or if an automatic recorder is used, the transition causes no disturbance of the record.

Assuming that the contact structure continues to rotate in counter-clockwise direction, the slide wire S2 continues in circuit until switch 3 is again operated to connect conductor 4 to contact C1 which is effected suitably before the contact structure reaches point 120 of slide wire S2, for example at about 115. This transition requires a change in position of contact C3, i. e., for the specific example given, the contact would need to be moved down 100 units on scale 1. Further rotation in the same direction repeats this cycle; rotation in reverse direction, simply reverses the order of the transitions.

Therefore the position of the contact structure C, which corresponds to the position of an element following or responsive to the changes of a condition, can be determined throughout its full 360 degrees of movement for either direction of movement, and for unlimited angular movement in either direction. For each position of contacts C1 and C2 within the sector of overlap of the high potential and low potential ends of the transmitting slide-wire, there are two possible positions of balance of contact C3 of the receiving slide-wire depending upon which of contacts C1, C2 is connected to the link circuit.

Fig. 2 illustrates an arrangement in which the contact structure is moved by a weather vane 5, which is illustrative of an instrument in which the primary transmitting element may rotate in either direction for an unlimited number of revolutions. An anti-aircraft gun turret is another example of such an element. The arm 6 which carries the contact structure of the transmitting slide wire rotates with the shaft 7 of the vane. The disk 8 carries contact rings, as shown, engaged by the contacts C1, C2 for connecting them to the stationary contacts of switch 3. As an alternative the contact structure may be fixed to a suitable stationary support, and the slide wire disk 8 secured to shaft 7. The movable contact 2 of the switch 3 is adapted to be operated from the shaft 7, automatically to effect the transition from one slide wire section to the other to

ensure continuity of the circuit between the transmitting and receiving slide-wires, and preferably there is interposed a lost motion device so that if the switch is operated for movement of the shaft 7 in one direction, it will not be operated at the same position of the shaft for movement of the shaft in a reverse direction, thus avoiding unnecessary operation of switch 3. Furthermore, the provision of this lost motion has the advantage that when the slide contact structure C is swinging within the range of about 100 to 120 the contact C3 of the receiving slide wire need not so often be shifted from one end to the other of the slide wire, or in the case of an automatic recorder, unnecessary oscillations of the recorder needle and the automatic rebalancing mechanism are avoided.

Specifically, upon the shaft 9 which carries the contact 2 of switch 3 is mounted a notched disk 10 which receives the pawl 11 biased by spring 12 to resist rotation of shaft 9. The upper end of the shaft 9 is connected through a spring 13 to a shaft 14 upon which is mounted a star wheel 15 or equivalent, having arms which extend into the path of the pins 16, 17 carried by the arm 18, secured to and rotatable with shaft 7. Assuming that the shaft 7 is rotated in clockwise direction as viewed in Fig. 2, the pin 16 engages one of the projections of the star wheel 15 and tensions the spring 13. When the torque of spring 13 is increased by movement of shaft 7 sufficiently to overcome the spring 12, pawl 11 is forced from the notch and allows contact 2 quickly to move through a quarter revolution, whereupon the pawl 11 drops into the next notch to arrest further movement. The actuation of the movable contact effects disconnection of contact C2 from conductor 4 and effects connection of contact C1. Assuming that the shaft 7 continues movement in clockwise direction, the second pin 17 engages projection of the star wheel 15 and effects another operation of switch 2. The spacing between the pins 16 and 17 is so related to the extent of displacement or staggering of the slide wire section, that the switch 2 is operated to ensure continuity of the circuit between galvanometer G and the slide wire, i. e., as the contact in circuit approaches the discontinuity of its slide wire, the switch is operated to connect the other slide wire in circuit as previously described.

It is therefore possible at all times accurately to determine the wind direction at the receiving station.

Since the star wheel 15 in the construction illustrated must be rotated through a considerable angle before effecting operation of switch 2, the switch 2 will not repeatedly operate if the shaft 7 oscillates back and forth within a narrow range, i. e., the mechanism described shifts the points at which the switch 2 is operated for opposite directions of rotation of shaft 7; for example, the switch may operate at 85% and 115% of a revolution for clockwise movement of the shaft 7, whereas for counter-clockwise movement the switch will operate at, for example, 75% and 105%; that is to say, the transfer point from slide wire S1 to slide wire S2 below 100% when rotating in one direction may be 10% higher than the transfer point of slide wire S2 to slide wire S1 in the decreasing direction; similarly, the transfer point from S2 to S1 in the increasing direction may be 10% higher above 100% of a revolution, than the return transfer from S1 to S2, when decreasing.

While the provision of this lost motion is desirable, it is not essential to the determination of the position of arm 18 for more than 360°.

For the example given the recording slide wire S3 may be calibrated zero to 120% revolution, or in degrees, radians, etc., or for wind direction the scale may be calibrated with north, for example, at the low end of the scale, followed by east, south, west, north, and ending with east, or south, depending upon the extent of overlap of slide wire sections S1, S2.

Referring to Fig. 3 there is illustrated a modification using the device of Fig. 2 in a Wheatstone bridge type of balanced network. The selected slide-wire section S1—S2 is included in two arms of the bridge, the position of the slide wire contact c determining the proportion included in each arm. A second slide wire S3 is included in the other two arms of the bridge, adjustment of its contact C3 permitting balance of the galvanometer G. In order that the measurements shall be substantially independent of the resistance of the leads, the bridge is preferably of the type shown in Leeds Patent 1,097,651, and accordingly there is provided the resistance S4 whose contact C4 is adjustable in unison with the contact C3 of the slide wire S3. The network may be energized by current from battery B1, or other direct current source, or by alternating current. In the latter case, galvanometer G is an alternating current instrument and its field is excited by current from the same source.

The two slide wire sections S1, S2 are in parallel between the conjugate points N', P' of the network and resistances R, R1 connected as in Fig. 1 are also of such magnitude that within the range 30—90 of the particular arrangement illustrated, the contacts C1, C2 are at the same potential.

The mode of operation of the transmitting slide wire is the same as in Fig. 1, i. e., as the contact in C1 or C2 circuit approaches the discontinuity of the slide wire section with which it is in engagement, the switch 3 is operated to change over to the other contact whose associated slide wire bridges the discontinuity or gap.

Fig. 4 illustrates a known type of self-balancing mechanism suitable for use at the receiving station; specifically it is of the type described in Leeds Patent 1,125,699.

Briefly, upon the controlled shaft 19 there is mounted the slide wire S3, of Fig. 1, or the slide wires S3 and S4 of Fig. 3. The needle 20 of the galvanometer G in response to unbalance of the network, including the transmitting and receiving slide wires and the link or transmission circuit between them, deflects in one direction or the other to effect corresponding displacement of the driving clutch member 21 while free of the driven clutch member 22 secured to shaft 19. Thereafter, in the cycle of operation, the driving clutch member 21 while in engagement with the driven clutch member 22 is returned by one or the other of the cams 23 secured to shaft 24 driven by motor 25, to its horizontal or neutral position effecting movement of the slide wire relative to its contact to rebalance the network.

The marker or recorder pen 26 is driven from the controlled shaft 19 through the pulley 27 and cord 28 to trace upon the record sheet 1a, the variations or changes in magnitude of the condition determining or controlling the position of the contact structure C of the transmitting slide wire.

For many uses, it is desirable to integrate the number of revolutions of shaft 7 of the trans-

mitting slide wire; for example, referring to Fig. 6, the shaft 7 may be driven through suitable mechanism diagrammatically illustrated by the float 30 for measuring the level of liquid in the tank 31 which generically represents a tank, well, stream, or the like. In moving from its maximum to minimum position, the float 30 may effect several revolutions of the shaft 7. To assume a specific instance for purposes of explanation, the float 30 may move through a distance of 100 feet, and the connections to shaft 7 may be such that the shaft 7 is rotated through ten revolutions. With the apparatus of Fig. 4, as thus far described, used with the transmitting system of Fig. 1, or of Fig. 2, the pen 26 will indicate the position of shaft 7 but will not distinguish between the revolutions, i. e., it will give the indication 6, for example, for 6 feet, 16 feet, 26 feet, etc. Accordingly it is desirable to add an attachment which will distinguish between such values. As shown in Fig. 4, the pen 26, or some other part of the actuating system, is provided with a contact 31a which when the pen reaches a position corresponding to one transition point of the transmitting slide wire, say 115% revolution, closes the circuit of a solenoid 32, or equivalent, to effect movement of armature 33 to advance the star wheel 34, or equivalent, one tooth, to shift the indicating or printing wheel 35 to the next highest number. Accordingly, as the float rises, each time the pen contact 31a bridges the contacts 36, 37, the wheel 35 is stepped to the next higher number, 10, 20, 30, etc. Similarly when the pen, in following the balancing of the network, reaches a position at which the other transition of the transmitting slide wire is effected, for example 5% revolution, the contact 31a of the pen engages the contacts 38, 39 to energize the solenoid 40 which attracts armature 41 to effect reverse movement of the indicating wheel 35, by one step, for falling movement of the float. Accordingly, the step by step mechanism integrates the number of complete revolutions of shaft 7, and pen 26 accurately indicates the position of shaft 7 for indication of fractional parts of a complete revolution.

The same end may be accomplished, by using instead of the step by step mechanism described, a second transmitting slide wire S5 suitably driven from shaft 7 so that its contact C7 moves from one end of the slide wire S5 to the other for the total range of movement of float 30; and this slide wire may be connected to a separate recorder of the type shown in Fig. 4. The pen of such recorder would travel across the scale only once for movement of the float 30 from maximum to minimum position, and the recorder connected to the slide wire S would serve as a vernier.

Another integrating arrangement is shown in Fig. 5. The step by step mechanism in this instance is actuated by movement of the contact of the transmitting slide wire, rather than by response of the receiving slide-wire apparatus. The recorder of Fig. 4, or equivalent, may be used for determining the position of the shaft 7 within the limits of a revolution, and the mechanism now described is for indicating the number of revolutions, adding for movement of shaft 7 in one direction, and subtracting for movement of shaft 7 in reverse direction.

The shaft 43 is connected to a suitable revolution counter 44, the hand 45 making for example one revolution for each ten revolutions of shaft 43 in one direction, and the hand 46 moving for example, one graduation for each complete rev-

olution of hand 45. This relation can be effected in any known manner common to counting trains, for example, by use of Geneva wheels, or gearing of suitable ratio.

- 5 The polarized relays 47, 48 are connected to the conductors 49, flow of current in one direction effecting movement of the armature 50 of relay 48 to advance the star wheel 51 one step, and flow of current in reverse direction effecting
10 movement of armature 52 of relay 47 to move the star wheel 53 one step in the reverse direction.

- The relays are controlled by a current reversing switch 54 consisting of the contacts 55, 56 having extensions projecting in the path of
15 movement of the pin 17', and contacts 58, 59 having extensions disposed in the path of movement of the pin 60. The pins 17' and 60 are carried by the contact arm 18, and therefore the positions of these pins in space are definitely related to the position of the contact structure of
20 the transmitting slide wire. All of the contacts 55, 56, 58, 59 are normally open. Each time the shaft 7 completes a revolution in a clockwise direction, for example in the direction indicated by
25 the arrow, Fig. 5, the pin 17' momentarily closes the contacts 55 and 56 so that an impulse of current flows from the battery B2 in the proper direction to effect energization of the relay 48 to effect rotation of shaft 43 one step in a corresponding or positive direction. For movement of
30 shaft 7 in counter-clockwise direction, the pin 60 effects momentary closure of the switches 58, 59 which effects flow of current from battery B2 through conductors 49 in reverse direction to effect energization of the relay 47 which notches
35 the shaft 43 one step in reverse or negative direction. The contacts are so located that 55, 56 are closed by pin 17' as pen 26 or equivalent reaches for example, point 101 of the recorder
40 scale, and contacts 58, 59 are closed by pin 60 as the pen in reverse direction passes point 99 of the scale.

- The combination of the recorder of Fig. 4 and an indicating device such as shown in Fig. 5,
45 permits the position of the float to be determined with great nicety throughout very large range of total float movement; for example, the position of the float may be accurately determined to within a small fraction of an inch throughout a
50 range of movement of many feet. Accuracy of high order is of prime importance when, for example, the tank 31 is a storage tank for large bodies of gasoline or other valuable liquid, as it is necessary that the metering of addition or
55 removal of fluid be very precise.

- When the float cable 61 is of considerable length, substantial error may be introduced because of variation in length of the cable with
60 change of temperature; i. e., increase in length of the cable due to increase of temperature has the same effect upon the position of shaft 7 as an increase in height of the liquid level and vice versa. This error may be compensated by the arrangement shown in Fig. 6a so that the accuracy
65 of the readings is independent of temperature. The Wheatstone bridge W includes in one arm thereof the resistance R6 of material having a suitably high temperature coefficient, for example, copper or nickel, and the other resistances
70 R7—R9, of maganin or other metal of negligible temperature coefficient, are preferably so proportioned, that the bridge is balanced for the lowest temperature to which the cable is subjected. For that temperature there is no flow of current
75 through the resistance R10 which is in one con-

jugate arm of the bridge. However, as the temperature increases the bridge becomes unbalanced and more and more current flows through resistance R10. The contact C10 adjustable along
5 this resistance is suitably mechanically connected, as generically indicated by the dotted line, to the float system so that the contact is moved from one end of the resistance to the other for movement of the float from one extreme of its range to the other. Therefore the position of the contact from the point N is proportional to the active
10 length of cable between the float and the pulley 62, and the drop of potential between the point N and contact C10 is proportional to the unbalance of the bridge, or temperature. The conductor 4' of the link circuit, instead of being connected
15 directly to the point N as in Fig. 1, is connected to the contact C10 of resistance R10 so that the potential difference between the conductors 4 and 4', which is impressed upon the receiving slide wire, is the algebraic sum of the voltages between
20 the point N and contact C10, and between point N and contact C1 or C2 depending upon which of the latter two is in circuit; i. e., the total voltage impressed on the transmitting end of the link circuit includes as a component a voltage proportional to temperature and the active length of cable.

Referring to Fig. 7, which illustrates another system utilizing the invention, when the contacts
30 63, 64 are in the position indicated, in engagement with contacts 65, 66, the circuit is substantially the same as in Fig. 3 and the same reference characters are used to identify like elements of the system; when contacts 63, 64 are
35 in their upper position in engagement with contacts 67, 68, the slide wire S5 is substituted for the slide wire S, i. e., the two arms of the bridge at the transmitting end are then comprised of the portions of S5, on either side of contact C7.
40

This system is adapted for use with the arrangement shown in Fig. 6 in which slide wire S5 makes one revolution for the total travel of float 30 and shaft 7 of slide wire S makes several revolutions. With contacts 63, 64 in their upper position the
45 bridge is balanced roughly to determine the position of float 30; i. e., to ascertain whether it is between say the limits 30 and 40 feet or between 10 and 20 feet; and with the contacts 63, 64 in the lower position, the location of the float
50 within those limits is precisely determinable.

Preferably, to minimize the number of wires between the transmitting and receiving stations, contacts 63, 64 are located at the transmitting station and their change over is effected from or
55 at the receiving station by utilizing the link circuit conductors. Specifically, the polarized relay 69 is included in the conjugate lead 4', and its armature 70 is suitably mechanically connected to contacts 63, 64 to move them into engagement
60 with contacts 65, 66 when energized by current of one polarity and to return to engagement with contacts 67, 68 when energized by current of opposite polarity.

The arrangement at the receiving station for
65 effecting operation of the relay may be similar to that described and claimed in Wunsch application Serial No. 560,152. Specifically, when the reversing switch 71 operable by handle 71' is in the position shown with its contact 72 bridging
70 the contacts 73, 74 and its contact 72' bridging the contacts 76 and 77, current from battery B3 flows through relay 69 in one direction, and when the handle is operated so that the contact 73 is connected to contact 76 and contact 74 to
75

contact 77, current flows from battery B3 through the relay in opposite direction. Therefore by manipulation of handle 71' at the receiving station, either slide wire S5, or slide wire S may be included in circuit at will; a suitable legend associated with handle 71' indicating the significant positions. To protect the galvanometer G from the relatively heavy relay-energizing current from battery B3, it is shunted or cut out of circuit by contact structure 75 operable by knob 71' concurrently with operation of the reversing switch 71.

When contacts 72, 72' are in their neutral or non-bridging positions, the galvanometer is in circuit for determination of the position of contact C7 or of the contact structure of slide wire S.

With an automatic recorder, such as shown in Fig. 4 the operation of switches 71 and 75 may be effected intermittently by cams, or other suitable structure, driven from the shaft 24. For this type of system, the recorder may be of the two point type, such as disclosed in the aforesaid Leeds patent, to distinguish the readings due to slide wire S5 from those of slide wire S.

The system of Fig. 8 is also suited for use with the arrangement of Fig. 6, or equivalent, to determine the position of a float or of any member or structure capable of controlling the slide wires S5 and S in response to changes of condition under measurement. When the contacts 78, 79 are in the position indicated, in engagement with contacts 80 and 81, the system in general is similar to Fig. 1, i. e., it is a potentiometer system in which the transmitting slide wire is of extent greater than 360° to measure with precision fractions of a revolution of a member capable of more than 360° of movement, such as shaft 7 of Fig. 6. When the contacts 78, 79 are in engagement with contacts 82, 83 the slide wire S5 is connected with the link circuit 4, 4', for determination of the integrated revolutions of shaft 7.

The movement of contacts 78, 79 may be effected by their mechanical connection to the star wheel 84 or equivalent, of the electromagnetic step-by-step device 85 having coil 86 and armature 87. The coil 85 as indicated is included in one of the conductors of the link circuit 4, 4' but the feeble unbalance current of the network is insufficient to effect movement of the armature 87.

For measuring, the contact 88 is in engagement with contact 89; to effect actuation of the step-by-step device 85 to shift from slide wire S5 for measurement of integrated revolutions to slide wire S for measurement of the fractional revolution, or vice versa, contact 88 is momentarily moved into engagement with contact 90 to connect battery B3 in circuit. Preferably contact 88 is mechanically connected to contact 91 for closing a shunt circuit around galvanometer G to protect it from the relatively heavy current from battery B3. In an automatic recorder, such as shown in Fig. 4 for example, contact 88 may be actuated periodically as by a cam 92 driven from the shaft 24.

For measuring either the position of contact C7, or C1, C2, the contact C3 of the receiving slide wire is connected to the link circuit through the movable contact 93 and contact sector 94 of a step-by-step device 95 whose coil 96 effects movement of armature 97 when contact 88 is actuated to include battery B3 in circuit.

The step-by-step devices 85 and 95 are syn-

chronized so that when contact 93 has moved into engagement with sector 98, the contacts 78 and 79 are in engagement with contacts 99, 100 which are connected across the terminals of the transmitting slide wires S and S5. Therefore, the galvanometer G deflects if there is unbalance between the total available voltages across the receiving and transmitting slide wires. Resistance R3 is adjusted, preferably automatically by mechanism similar to that described in the aforesaid Leeds Patent 1,125,699, until balance is obtained. The receiving slide-wire is in effect recalibrated and there is no need of an operator or service man travelling to the transmitting station for readjustment of resistance R2 to recalibrate because of variation in voltage of battery B due to aging, etc.

It is not necessary that the transmitting slide wire S be divided into two sections in order to obtain measurements throughout a complete revolution or more. Referring to Figs. 9 and 10, the slide wire S is comprised of a single continuous section, suitably greater than 360° with its overlapping ends Se and SE suitably spaced. The contact structure therefor is divided into contact elements C1 and C2. Within the angle or sector of overlap, the upper contact C1, Fig. 10, engages only the end portion SE and the lower contact C2 engages only the lower end portion Se and preferably for substantially the remaining angle, both of the contacts engage the wire which preferably, as shown, is helically wound on disk 8.

The switch 3, not shown in Fig. 10 for clarity, but constructed and operated as above described in connection with Fig. 2, transfers the connection to the link circuit from C1 to C2 before contact C1 passes beyond the end of overlapping section SE for counter-clockwise movement of arm 18, and transfers from C2 to C1 before C2 passes beyond overlapping section Se for clockwise movement of the arm.

Operation of this modification can best be understood by consideration of the diagram of Fig. 9. It is first assumed that the contacts C1, C2 are in the dotted line position, both in contact with the slide wire. The resistor R11 in series with the slide wire is equal in magnitude to the resistance of the slide wire between contacts C1, C2 so that the voltage drop between the point X and contact C1 is equal to the voltage drop between point Y and contact C2. (The conductor between Y and the end Se of the slide wire is of negligible resistance).

Therefore within the region for which both contacts C1 and C2 are in engagement with the slide wire, the voltage impressed on the link circuit is the same regardless of which of the contacts is connected by switch 3, since the transition from one to the other is accompanied by concurrent shift from point X to point Y; i. e., when contact 2 of switch 3 is in upper position to connect slide wire contact C1 to conductor 4, contact 2A of the switch is in position to connect conductor 4' to point X to include the voltage drop across resistor R11 and when contact 2 of switch 3 is in its lower position to connect slide wire contact C2 to conductor 4, contact 2A of switch 3 is in position to connect conductor 4' to the point Y to exclude the voltage drop across resistor R11.

There is no position of arm 18 which cannot be determined at the receiving station, regardless of the number of revolutions of shaft 7 in either direction. The slide wire construction of Fig. 10 can be substituted for the two section slide wire

of any of the preceding modifications. It is of course immaterial whether the contact structure C1, C2 is rotatable and the slide wire disc 8 stationary or vice versa.

- 5 In all modifications, the transmitting slide wire is more than 360° in angular extent; the receiving slide wire if arcuate may be more or less than 360°, or it may be a straight wire or on a straight form; for automatic recording, the receiving slide wire as indicated is usually circular and less than 360°.

For simplicity of explanation, batteries have been shown in Figs. 1, 3, 6a, 7, 8, and 9 as sources of current for the measuring network. It is to be understood however, that other sources of current, direct or alternating, may be used. In the modifications using polarized relays batteries B2, (Fig. 5) B3 (Fig. 7) are generically illustrative of any direct current source.

- 20 In the potentiometer system shown in Fig. 11, the two overlapping sections S1, S2 of slide wire S are connected in series, as by conductor Cs of negligible resistance, instead of in shunt to each other, as in Figs. 1 and 2 for example. The resistance R13 is included and excluded from circuit insofar as impression of its voltage drop upon the link circuit is concerned concurrently with changeover from contact C2 to C1 and vice versa. The resistances R13 and R12 are of such magnitude that the drop of potential across each of them is equal to difference in potential between points 30 and 90 of either slide wire section. The changeover from contact C1 to C2 or vice versa within the range 30—90 does not therefore require or effect movement of contact C3 since the concurrent inclusion or exclusion of resistance R13 by contact 2a of switch 3 produces a voltage change equal and opposite to that produced by the changeover. In general, the resistance R13 has the same purpose as resistance R11 of Fig. 9.

The movement of contact structure C relative to slide wire S is effected by changes in the condition under measurement, and as in all other modifications, there is no position of the contact structure which does not permit balance of the network regardless of the direction or number of revolutions.

- The modifications shown in Fig. 12 is for use with alternating current. The slide wire SS or voltage-dividing impedance is comprised of two coils SS1 and SS2, shown for simplicity as wound on separate cores of magnetic material, which coils are the equivalent of the slide wire sections S1, S2 of Fig. 1 and other modifications. The discontinuities between the terminals of the coils are staggered so that at least one or the other of the contacts C1, C2 of the movable contact structure is at all times in engagement with the slide wire. As in the other modifications switch 3 is operated to ensure connection to the receiving slidewire S3 for all settings of the transmitting wire.

The energizing current for the receiving slide-wire is supplied by transformer BB1 for example. Current for the transmitting slide wire is supplied by transformer BB. The proper potentials for the terminal 90 of coil SS1 and terminal 30 of coil SS2 may be obtained from the taps t, t1 of the secondary of transformer BB.

Although the coils are shown in parallel, they may be connected in series as in Fig. 10. The inductive type of slide-wire may also be used in the Wheatstone bridge circuit of Fig. 2.

- 75 The mode of operation for any of these ar-

rangements will be understood from the detailed description of the operation of the preceding arrangements.

While I have disclosed specific modifications of my device and illustrated and described certain uses thereof, it is to be understood that my invention is not limited thereto but is co-extensive in scope with the appended claims.

For brevity, the term slide-wire as used in the claims is generic to a voltage-dividing impedance consisting substantially entirely of resistance or of reactance, or having any desired ratio of reactance to resistance.

What I claim is:

1. An electrical measuring system comprising a transmitting station, a receiving station, a link circuit between said stations, a slide wire at said transmitting station extending more than 360° and having a low potential portion overlapping a higher potential portion, contact structure having contact elements for engaging said slide wire, one of said elements engaging said low potential portion while the other engages said high potential portion, structure responsive to changes of a condition for effecting relative rotation of said slide wire and contact structure of more than 360°, and switching means for selectively connecting one or the other of said contact elements to said link circuit.

2. An electrical measuring system comprising a transmitting station, a receiving station, a link circuit between said stations, a slide wire at said transmitting station extending more than 360° and having a low potential portion overlapping a higher potential portion, contact structure having contact elements for engaging said slide wire, one of said elements engaging said low potential portion while the other engages said high potential portion, structure responsive to changes of a condition for effecting relative rotation of said slide wire and contact structure of more than 360°, and switching means operated by said responsive structure selectively to connect one or the other of said contact elements to said link circuit.

3. An electrical system for determining all positions of a member capable of more than 360° of movement comprising a slide wire having an angular extent of more than 360°, contact structure therefor mechanically coupled to said member and having contact elements constructed and arranged individually to engage the overlapping portions of said slide wire, a receiving slide wire less than 360° in angular extent, a transmission circuit between said slide wires, and switching means for selectively connecting one or the other of said contact elements to said transmission circuit.

4. An electrical measuring system comprising a transmitting station, a receiving station, a link circuit between said stations, a slide wire at said transmitting station extending more than 360° and having a low potential portion overlapping a higher potential portion, contact structure having contact elements for engaging said slide wire, one of said elements engaging said low potential portion while the other engages said high potential portion, structure responsive to changes of a condition for effecting relative rotation of said slide wire and contact structure of more than 360°, switching means operated by said responsive structure selectively to connect one or the other of said contact elements to said link circuit, including a lost motion connection to

avoid repeated operation of said switching means for oscillation of said responsive structure within a narrow range of movement.

5 5. An electrical measuring system comprising a receiving potentiometer, a transmitting potentiometer, a link circuit between said potentiometers, said transmitting potentiometer comprising a slide-wire of more than 360° in angular extent, and having overlapping end portions, 10 contract structure therefor having contact elements constructed and arranged individually to engage said end portions, structure for moving said contact structure for more than 360°, and switching means for selectively connecting one 15 or the other of said contact elements to said link circuit.

6. A electrical measuring system comprising a Wheatstone bridge having two arms at a transmitting station and two arms at a receiving station, said transmitting arms comprising a slide 20 wire of more than 360° in angular extent and having overlapping end portions, contact structure therefor having contact elements constructed and arranged individually to engage said end portions, structure for moving said contact 25 structure for more than 360°, and switching means for selectively connecting one or the other of said contact elements to a conjugate conductor of the bridge extending between said stations.

7. An electrical measuring system comprising a slide-wire having arcuate sections of less than 360° staggered to complete more than 360°, contact structure therefor comprising contact elements 30 constructed and arranged individually to engage said different sections to effect continuous contact between said slide wire and said contact structure, a transmission circuit, and switching means for selectively connecting one or the 35 other of said contact elements to said transmission circuit.

8. An electrical measuring system comprising a slide-wire having arcuate sections of less than 360° staggered to complete more than 360°, contact structure therefor comprising contact elements 40 constructed and arranged individually to engage said different sections to effect continuous contact between said slide wire and said contact structure, a transmission circuit, means for effecting 45 relative movement of said slide wire to said contact structure of more than 360°, and means for effecting connection of said slide wire to said transmission circuit for all relative positions of 50 said contact structure comprising switching means operated by said first means for transferring connection of said transmission circuit 55 from a contact approaching a gap of its slide-wire section to a contact engaging a slide wire section bridging said gap.

9. An electrical measuring system comprising a slide wire having sections of less than 360° 60 staggered and overlapping to complete more than 360°, contact structure therefor comprising contact elements constructed and arranged individually to engage said different sections, means for 65 effecting rotation of said contact structure for more than 360°, external circuit connections direct to the high potential end of one section and to the low potential end of the other section, an 70 impedance between the high potential ends of said sections, an impedance between the low potential ends of said sections, said impedances being of such magnitude that within the region between the low potential end of said second section 75 and the high potential end of said first sec-

tion, said contact elements are at the same potential.

10. An electrical measuring system comprising a potentiometer slide wire having sections of less than 360° staggered and overlapping to complete 5 more than 360°, contact structure therefor comprising contact elements constructed and arranged individually to engage said sections, means for effecting rotation of said slide wire 10 relative to said contact structure of more than 360°, a source of current, connections for connecting said sections in parallel across said source, and resistances connected respectively 15 between the high potential end of one section and one terminal of said source and between the low potential end of the other section and the other terminal of said source, said resistances being of such magnitude that said contact elements for a substantial part of 360° are at the 20 same potential.

11. An electrical measuring system comprising a Wheatstone bridge slide-wire having sections of less than 360° staggered and overlapping to 25 complete more than 360°, contact structure therefor comprising contact elements constructed and arranged individually to engage said sections, means for effecting rotation of said slide wire relative to said contact structure of more than 360°, connections for connecting said sections in parallel 30 between conjugate points of said bridge, and impedances included respectively in the connection from the high end of one section to one of said conjugate points and in the connection from the low end of the other section to the other of 35 said conjugate points, and of such magnitude that said contact elements are at the same potential for a substantial part of 360°.

12. An electrical measuring system comprising a transmitting system including a slide wire at said transmitting station of angular extent 40 greater than 360°, contact structure therefor, rotatable structure for effecting relative rotation of said slide wire and contact structure of more than 360°, a receiving system comprising a slide 45 wire at said receiving station connected to said first slide wire for determining at said receiving station the position of said rotatable structure within a complete revolution, and means at said receiving station operated by means included in 50 one of said systems to integrate the revolutions of said rotatable structure.

13. An electrical measuring system comprising a transmitting station, a receiving station, a link circuit between said stations, a slide wire at said transmitting station having an angular extent in 55 excess of 360°, contact structure therefor including contact elements one or the other of which engages said slide wire depending upon the relative position of said slide wire and contact structure, rotatable structure for effecting relative 60 movement of said slide wire and contact structure of more than 360°, switching means operated by said rotatable structure to effect transfer of a link circuit connection from one of said contact elements to the other at predetermined positions of said contact structure, a self-balancing 65 recorder at said receiving station, a reversible step-by-step device at said receiving station, and means for controlling said device to integrate the revolutions of said rotatable structure. 70

14. An electrical measuring system comprising a transmitting station, a receiving station, a link circuit between said stations, a slide wire at said transmitting station having an angular extent 75 in excess of 360°, contact structure therefor in-

cluding contact elements one or the other of which engages said slide wire depending upon the relative position of said slide wire and contact structure, rotatable structure for effecting relative movement of said slide wire and contact structure of more than 360°, switching means operated by said rotatable structure to effect transfer of a link circuit connection from one of said contact elements to the other at predetermined positions of said contact structure, a self-balancing recorder at said receiving station, a reversible step-by-step device at said receiving station, and switching devices operated selectively by said rotatable structure in accordance with its direction of rotation and for each complete revolution to control said step-by-step device for integration of the revolutions of said rotatable structure.

15. An electrical measuring system comprising a slide-wire having arcuate sections of less than 360° staggered to complete more than 360°, contact structure therefor comprising contact elements adapted to engage said different sections, a source of current, means for connecting said sections in series to said source of current, a transmission circuit, and switching means for selectively connecting one or the other of said contact elements to said transmission circuit.

16. An electrical telemetric system comprising a transmitting system including a transmitting element capable of unlimited revolutions in either direction, and means controlled thereby to produce an electrical effect whose magnitude is uniquely representative of the displacement of said structure for more than 360°, a receiving sys-

tem including means responsive to said effect for determination of the displacement of said member, and a link circuit of not more than three conductors for connecting said transmitting system to said receiving system.

17. An electrical telemetric system comprising a transmitting system including a transmitting element capable of unlimited revolutions in either direction, and means controlled thereby to produce an electrical effect whose magnitude is uniquely representative of the displacement of said structure for more than 360°, a receiving system including means responsive to said effect, structure controlled by said responsive means to indicate the position of said element and having a limited range of movement, and a link circuit of not more than three conductors for connecting said transmitting system to said receiving system.

18. An electrical telemetric system comprising a transmitting system including a transmitting element capable of unlimited revolutions in either direction, and means controlled thereby to produce an electrical effect whose magnitude is uniquely representative of the displacement of said structure for more than 360°, a receiving system including means responsive to said effect, structure controlled by said responsive means to indicate the position of said element and having a limited range of movement, a link circuit of not more than three conductors for connecting said transmitting system to said receiving system and integrating means controlled by said structure to integrate the revolutions of said element.

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