

June 22, 1948.

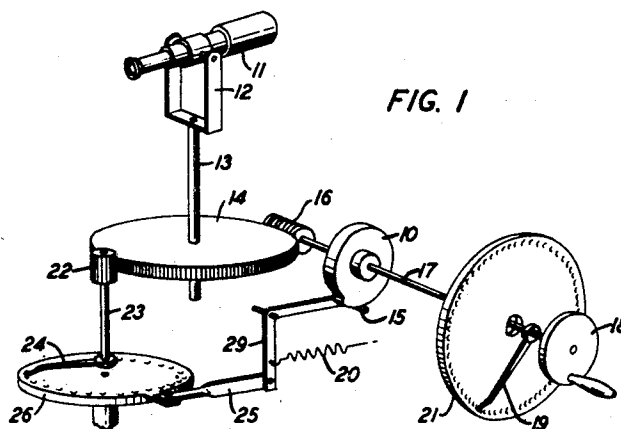
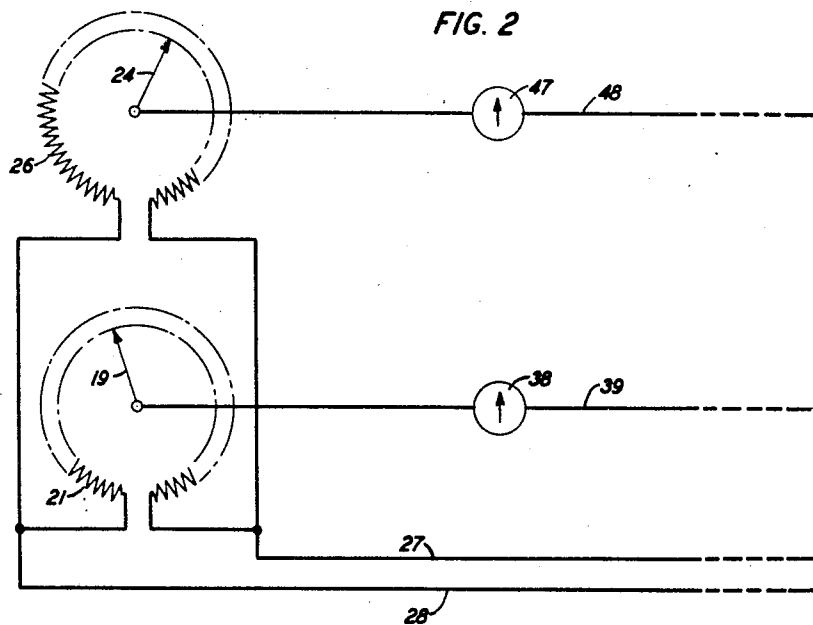
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2,443,623

DATA TRANSMITTING AND INDICATING SYSTEM

Filed July 22, 1942

4 Sheets-Sheet 1



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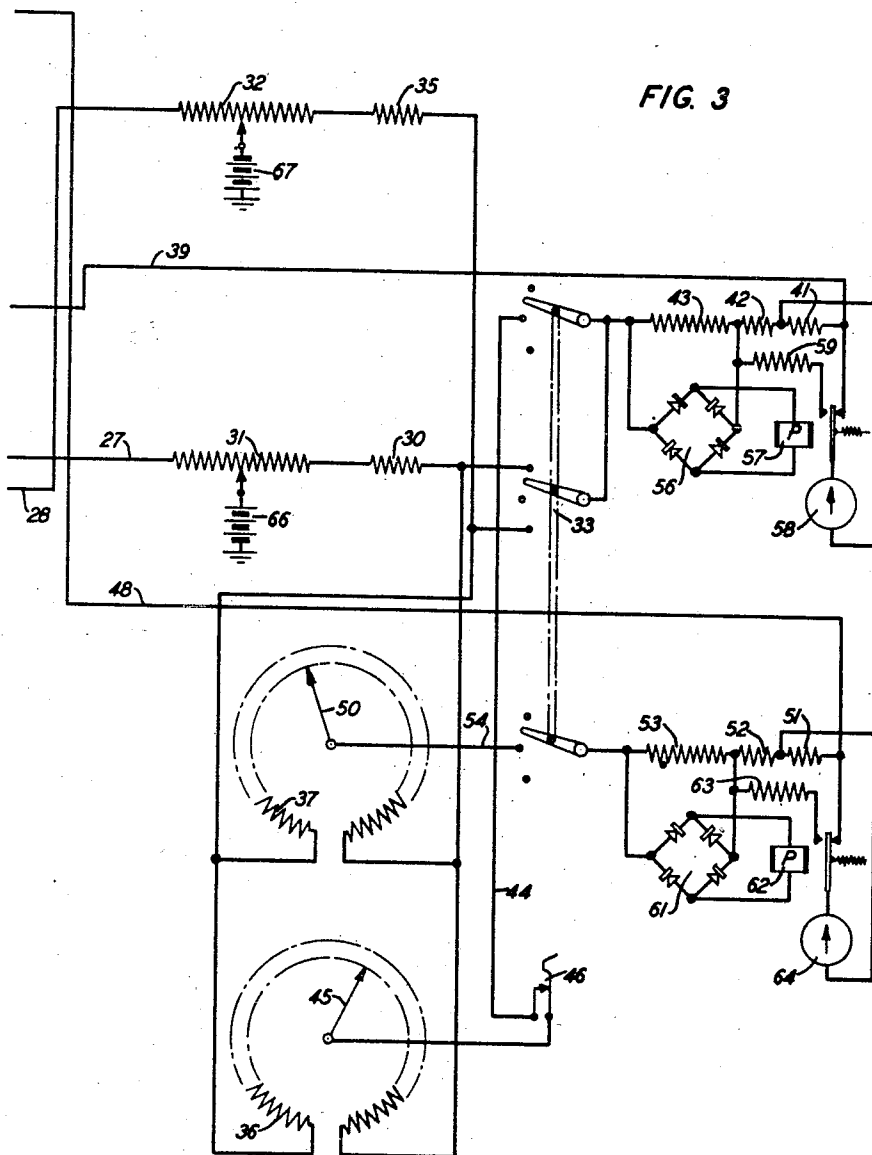
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DATA TRANSMITTING AND INDICATING SYSTEM

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4 Sheets-Sheet 2



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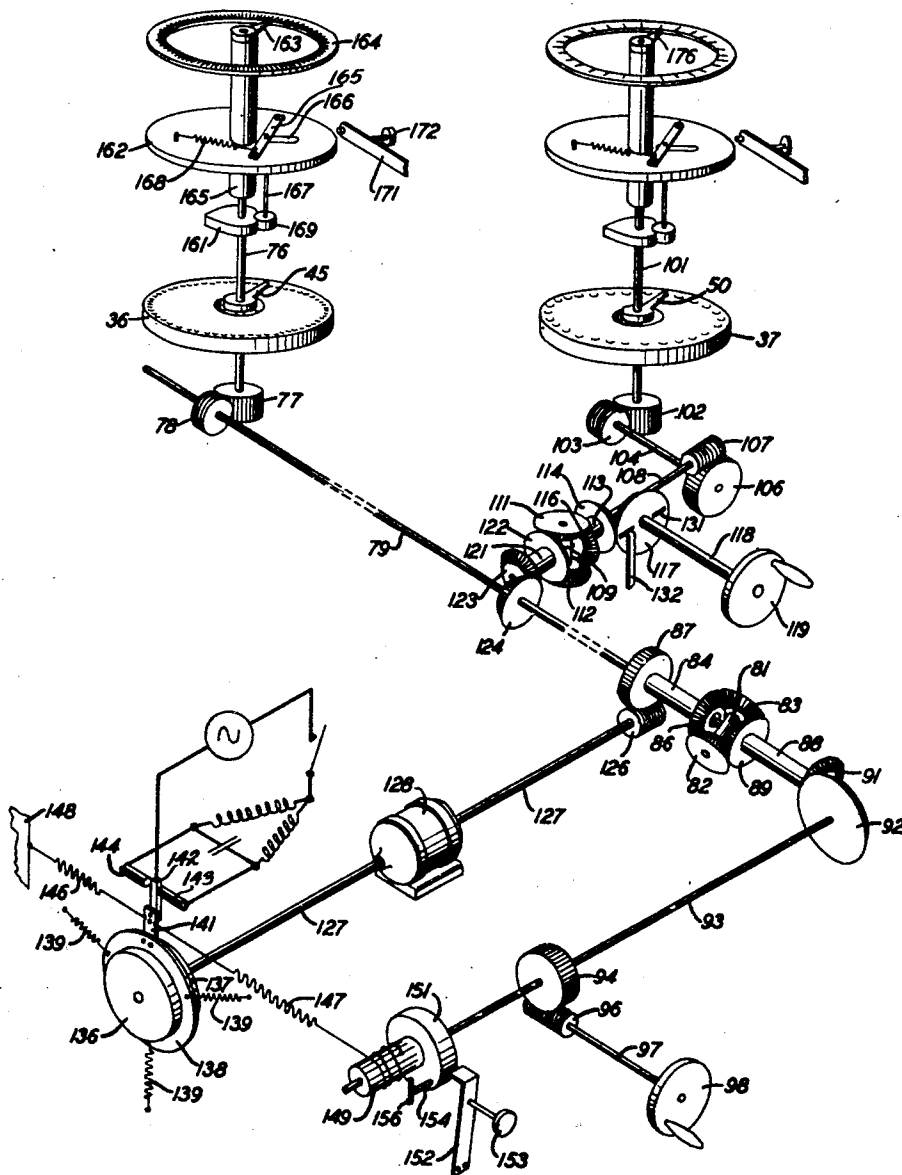
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DATA TRANSMITTING AND INDICATING SYSTEM

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FIG. 4



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DATA TRANSMITTING AND INDICATING SYSTEM

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FIG. 5

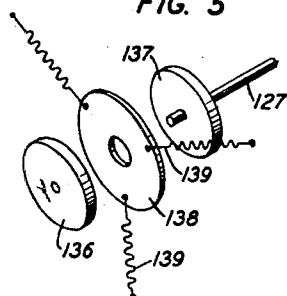
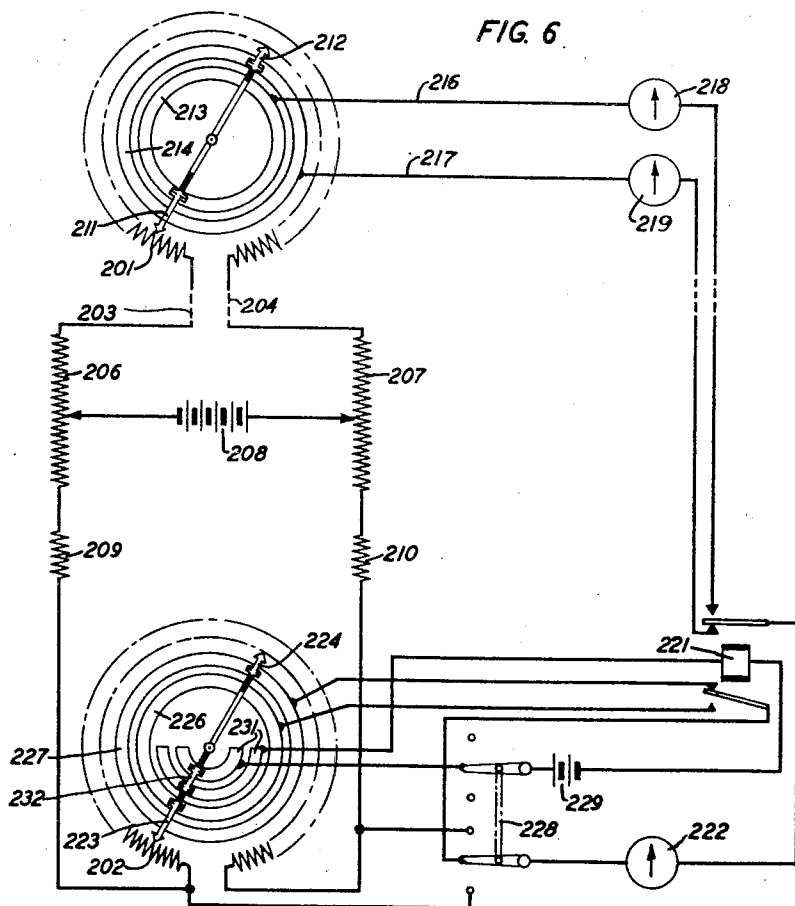


FIG. 6



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DATA TRANSMITTING AND INDICATING
SYSTEM

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Application July 22, 1942, Serial No. 451,857

8 Claims. (Cl. 177—351)

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This invention relates to signaling systems and particularly to systems for the transmission of data representing the readings of variably settable registering instrumentalities.

An object of the invention is to provide a simple and effective method and means for balancing communication lines to nullify or minimize effects of variations in line leakage resistance.

Another object of the invention is to reproduce substantially synchronously at a receiving station, a continuously varying reading of the registering instrumentality at a transmitting station.

Another object of the invention is to provide manually operable means for controlling the substantially synchronous reproduction of a reading at a receiving station in order to compensate for changes in the rate of variation of the reading at the transmitting station.

Another object of the invention is to provide an improved speed regulator device for an electric motor.

Another object of the invention is to provide for arresting continuously driven registers for the purpose of taking a reading while the driving mechanism therefor continues to operate and accumulate movement, and to bring the registers into step with the driving mechanism upon release of the registers.

Another object of the invention is to automatically reverse the connection and alter the sensitivity of a polarized current responsive device upon sudden reversal of the direction and increase in the amount of current applied thereto.

In general the invention contemplates the association with a registering instrumentality at a transmitting station of potential dividers for units and fractions of units of measurement of a quantity or characteristic. The potential dividers are so associated with the registering instrumentality that the potential divider which represents fractions of units is operable through one full cycle, or revolution in the case of a circular potential divider, for each unit of measurement and the potential divider which represents units encompasses a convenient plurality of such units in one cycle or revolution of operation.

The potential dividers at the transmitting station are connected across two power supply conductors which extend to the receiving station where potential dividers of an equal number and kind are connected across the two conductors. A source of direct current signaling potential at the receiving station is connected across the two power supply conductors through potentiometers

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by means of which compensation may be made for variations in the resistance of the two power supply conductors. The contactors of the potential dividers at the transmitting station are connected through individual conductors to the contactors of the corresponding potential dividers at the receiving station and each of these conductors has associated with it at the receiving station and preferably also at the transmitting station, a current registering device such as a galvanometer.

The contactors of the potential dividers at the receiving station are interconnected through gearings so as to be operable in the same ratio as the contactors of the potential dividers at the transmitting station. Preferably there is associated with each of the potential dividers at the receiving station a scale and pointer indicating device whereby the settings of the potential dividers may be observed visually in terms of units and fractions of units of measurement at any time. Although a manually operable driving means for the contactor at the receiving station is provided, it is preferable to provide also a power-driven mechanism for driving the contactors of the potential dividers, with manually operable means for varying the speed of the driving means and with regulator means for maintaining the speed of the driving means constant for any setting of the manually operable speed controlling means.

With the power supply lines properly balanced with respect to their resistance, any discrepancy between the settings of the potential dividers at the transmitting station with reference to the potential dividers at the receiving station will result in a potential difference between the ends of the conductors which control the galvanometers, so that current will flow through those conductors and the galvanometer armatures and pointers will be deflected from their zero positions. This discrepancy may be eliminated and the contactors of the potential dividers at the receiving station brought into exact correspondence with the contactors of the potential dividers of the transmitting station by rotating the contactors at the receiving station in the direction to reduce the deflection of the galvanometers until the galvanometers show zero deflection.

When the measurement being registered by the registering instrumentality at the transmitting station is continuously varying in the same direction at substantially uniform rate, the power driving mechanism for the contactors at the receiving station may be operated at such speed under the proper adjustment of the manually

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operable speed changer that the contactors for the potential dividers at the receiving station continuously rebalance the galvanometer conductors which are being unbalanced continuously at the transmitting station so that the galvanometers continue to show zero deflection and the indicators associated with the potential dividers at the receiving station at all times indicate the reading of the registering instrumentality at the transmitting station. It is also within the contemplation of the invention to provide similar power-driven mechanism with manually operable speed variation control for driving the registering device and the associated potential divider contactors at the transmitting station, to cause the registering instrumentality to register continuously the value of the characteristic that is being measured where such value is changing at substantially uniform rate.

In case the potential divider contactors at the receiving station are permitted to lag behind the contactors at the transmitting station to the extent that a potential divider contactor at the transmitting station moves across the gap from one of the end contacts to the other, before the contactor of the corresponding potential divider at the receiving station leaves the corresponding end of its potential divider, the full potential of the power supply will be applied between the ends of the galvanometer conductor associated with the contactors. This causes extreme deflection of the galvanometer in the reverse of the direction in which the potential divider at the transmitting station had been previously tending to deflect it and gives an apparent indication that the contactor at the receiving station should be reversed to restore zero reading of the galvanometer. To prevent the occurrence of this false indication and also the extreme deflection of the galvanometer, the receiving station is provided with a rectifier associated with each of the galvanometer conductors and each of the rectifiers controls a relay which is effective to reverse the connection of the galvanometer to its conductor and also to reduce the sensitivity of the galvanometer when the full potential between the power supply conductors is impressed across the ends of a galvanometer conductor.

In accordance with an alternative embodiment of the invention, corresponding potential dividers at the transmitting station and receiving station are provided with two diametrically opposed contactors insulated from each other and driven as a single element. The contactors at the transmitting station are connected through individual conductors to front and back contacts of a relay, the cooperating armature of which is connected through a galvanometer to another armature of the relay, the cooperating front and back contacts of which are connected to the two contactors of the potential divider at the receiving station in the same relation as the contactors of the potential divider at the transmitting station. When the relay is energized one of the contactors at the transmitting station is connected through the front contacts and armatures of the relay and through the galvanometer to the corresponding contactor of the potential divider at the receiving station. When the relay is de-energized the other contactor at the transmitting station is connected through the back contacts and armatures of the relay and through the galvanometer to the corresponding contactor of the potential divider at the receiving station. Switching contacts are associated with the poten-

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tial divider at the receiving station for opening and closing the energizing circuit of the relay in such relation to the movement of the contactors that when either contactor is within a predetermined distance of the end contact of the potential divider, and therefore is in prospect of passing directly from one to the other of the end contacts, that contactor and the corresponding contactor at the transmitting station are disconnected from the galvanometer, by the relay, and the other contactors are connected to the galvanometer. This arrangement prevents the sudden connection to the galvanometer of the full voltage across the potential divider due to passage of a potential divider contactor directly from one of the end contacts to the other.

For a complete understanding of the invention, reference may be had to the following detailed description to be interpreted in the light of the accompanying drawings wherein:

Fig. 1 is a schematic perspective view showing the data registering device at the transmitting station with the potential dividers associated therewith;

Fig. 2 is a circuit diagram of the electrical system at the transmitting station;

Fig. 3 is a circuit diagram showing the electrical system at the receiving station;

Fig. 4 is a schematic perspective view showing the potential dividers and data registering devices at the receiving station and speed regulated power driving mechanism for those potentiometers and registers;

Fig. 5 is an exploded perspective view of a magnetic drag unit; and

Fig. 6 is a circuit diagram of a modified transmission system.

Referring now to the drawings and particularly to Fig. 1, the reference numeral 11 designates an optical device through which a distant object may be observed. Optical device 11 is supported by horizontally extending trunnions in a U-shaped bracket 12 which is secured to a vertically extending shaft 13. Shaft 13 is keyed or otherwise secured to a worm wheel 14 which is engaged by a worm 16 secured to a shaft 17. The ratio between worm wheel 14 and worm 16 is preferably 360 to 1 so that optical device 11 is moved through an angle of 1 degree in a horizontal plane for each revolution of shaft 17.

Shaft 17 has secured thereto a crank wheel 18 by means of which rotation may be imparted to the shaft and also has secured thereto a contact arm 19 of a potential divider 21 which is stationarily mounted. Potential divider 21 preferably has 100 uniformly spaced electrical contacts arranged in a circle so that movement of contact arm 19 from one contact to the next will represent $1/100$ of 1 degree of movement of optical device 11.

A pinion 22 secured to a shaft 23 meshes with the worm wheel 14. Shaft 23 has secured thereto the contact arm 24 of a potential divider 26. Due to considerations of physical dimensions, it is considered preferable not to attempt to provide 360 contacts on the potentiometer 26, one to represent each angle of arc through which optical device 11 may be rotated, and preferably a smaller number of contacts is provided which number is a factor of 360 such as 30, for example. With that number of contacts contained in potentiometer 26, the ratio of the number of teeth on the worm wheel 14 to the number of teeth on pinion 22 would be 12 to 1 so that potentiometer contact arm 24 would execute exactly

twelve revolutions for one revolution of optical device 11, and advancement of the contact arm from one contact to an adjacent contact represents 1 degree of angle of rotation of the optical device 11.

The potential dividers 20 and 21 register degrees and hundreds of a degree, respectively, and it is desirable that the contact arm 24 of potential divider 20, which rotates steadily as the worm wheel 14 is rotated steadily, shall not correspondingly advance steadily from one contact to another, but shall remain in engagement with one contact throughout as much of one revolution of contact arm 19 of potential divider 21 as is feasible and shall advance to the next contact concomitantly with advance of the contact arm 19 through a very small angle. To this end, a cam 10 having uniformly increasing radius from its nadir portion to its apex and having a sharp drop off is secured to shaft 17. The periphery of cam 10 is continuously engaged by a follower pin 15 carried by a bell crank 29 which is spring biased by tension spring 20 to maintain engagement between cam 10 and pin 15. A link 25 connects bell crank 29 to the housing of potential divider 20 and this housing is mounted for limited angular rotation about its axis. The rate of change of the radius of cam 10 is such that it imparts to the housing of potential divider 20 angular movement which is equal to that imparted to contact arm 24 by worm wheel 14 through pinion 22, so that throughout a very large portion of each revolution of cam 10 there is no relative movement between contact arm 24 and the potential divider housing 20 and thus there is no relative movement between the contact arm and the contact which it is engaging. As the sharp drop off in cam 10 traverses follower pin 15 going in either direction, the housing of potential divider 20 is quickly shifted with respect to the contact arm 24 to bring one or the other of the adjacent contacts into engagement with the contact arm 24. Cam 10 is so oriented with respect to potential divider contact arm 19 that the shifting of the housing of potential divider 20 with respect to contact arm 24 begins and ends at substantially equal angular distances each side of the zero position of potential divider contact arm 19, such as from .99 degree to .01 degree.

The two potential dividers appearing in Fig. 1 are shown in schematic form in Fig. 2, identified by the same reference numerals. Although the potential dividers have been shown in Fig. 2 as comprising continuous resistance windings and slider contact arms, a simple way in which such potential dividers may be constructed from a practical standpoint is to provide fixed resistors of equal value bridging each two adjacent contacts, with the exception that one such pair of contacts has no bridging resistor and the source of potential difference which is to be distributed over the potential divider is connected to these two contacts.

The hundredths of a degree and degree potential dividers 21 and 20 are each bridged across a pair of power supply conductors 27 and 28 which extend to the receiving station shown in Fig. 3. Power supply conductor 27 connects at the receiving station to one terminal of a line balancing potentiometer 31 and power supply conductor 28, connects to the corresponding terminal of a similar balancing potentiometer 32. The other terminal of potentiometer 31 is connected through a fixed resistor 30 to the upper

terminal of the middle bank of a three-point three-bank switch 33 and also to one terminal of each of the potential dividers 36 and 37 which are hundredths of a degree and whole degree potential dividers respectively and are identical with the potential dividers 21 and 20, respectively, at the transmitting station. The other terminal of potentiometer 32 is connected through resistor 35 to the lower contact of the middle bank of multiple bank switch 33 and to the other or left-hand terminals of the potential dividers 36 and 37. The contactor of line balancing potentiometer 31 is connected to battery of one polarity and the contactor of line balancing potentiometer 32 is connected to battery of the opposite polarity. These two contactors may be connected to the terminals of one battery or other source of direct current potential.

The contact arm 19 of hundredths degree potential divider 21 is connected to one terminal of a galvanometer 38, the other terminal of which is connected to galvanometer line conductor 39 which extends to the receiving station and is connected to one end of a series of resistors 41, 42 and 43. The other end of this series is connected to the switch arm of the upper bank of switch 33 and from the middle contact of the upper bank, which is the contact engaged by the switch arm except when line balancing operations are in progress, as will be described later, is connected through conductor 44 and normally closed key 46 to the contact arm 45 of hundredths potential divider 36 at the receiving station. Similarly, the contact arm of the whole degree potential divider 20 is connected to one terminal of a galvanometer 47, the other terminal of which is connected to a second galvanometer line conductor 48 which extends to the receiving station and connects to the right-hand end of a series of resistors comprising the resistors 51, 52 and 53, the left-hand end of which is connected to the lower switch arm of switch 33. The middle contact of the lower bank of the gang switch is connected by conductor 54 to the contact arm 50 of the whole degree potential divider 37 at the receiving station.

The input terminals of a full wave rectifier are connected to the terminals of resistor 43 so that the rectifier is in shunt with the resistor and the winding of a spring-biased polar relay 57 is connected across the output terminals of the rectifier 56. The back contact of relay 57 is connected to the right-hand terminal of resistor 41 and the armature of the relay is connected to one terminal of a galvanometer 58, the other terminal of which is connected to the left-hand end of resistor 41. Thus when relay 57 is deenergized, current flowing through resistor 41 in either direction will develop a potential difference across this resistor and this potential difference will be impressed across galvanometer 58 to produce a corresponding deflection of the galvanometer. The front contact of relay 57 is connected through a resistor 59 to the left-hand terminal of resistor 42 and the latter resistor has the same value as resistor 41. Thus when relay 57 is energized, galvanometer 58 will be connected across resistor 42 instead of across resistor 41 and in the reverse direction or polar sense, and in addition resistor 59 will be connected in series with galvanometer 58 to limit the flow of current through the galvanometer resulting from the potential difference across resistor 42.

Similarly, the input terminals of a full wave rectifier 61 are connected across resistor 53 and

a polar relay 62 is connected to the output terminals of rectifier 61. A resistor 63 is connected between the left-hand end of resistor 52 and the front contact of relay 62 and the back contact of the relay is connected to the right-hand end of resistor 51. The armature of relay 62 is connected to one terminal of a galvanometer 64, the other terminal of which is connected to the left-hand end of resistor 51.

Since the communication system shown in the combination of Figs. 2 and 3 serves only to communicate the setting or movement of the optical device shown in Fig. 1, a supplemental two-way communication system for transmitting other intelligence between the transmitting and receiving stations is assumed. Such supplemental communication system may be telephone or telegraph. In order to balance the resistance of the power supply lines 27 and 28, which operation is performed at the receiving station, the attendant at the receiving station communicates to the attendant at the transmitting station instructions to adjust the hundredths degree potential divider so that the contact arm engages the contact to which power supply line conductor 27 is directly connected. It has been found convenient to so relate the hundredths degree potential divider to the shaft 17 that the right and left-hand end contacts of the potential divider represent readings $50/100$ and $51/100$, respectively, from which it will follow that the zero contact will be about at the midpoint of the potential divider. Accordingly, the attendant at the receiving station may instruct the attendant at the sending station to adjust the crank wheel 18, which may be graduated to the scale of 100, to the setting 50. The attendant at the receiving station, thereupon operates switch 33 to bring the switch arms into engagement with the upper contacts of the three banks.

The operations outlined in the foregoing paragraph establish a Wheatstone bridge circuit having the batteries 66 and 67, which have their positive and negative poles respectively connected to the contact arms of the potentiometers 31 and 32, respectively, connected in series-aiding relation across two opposite apices of the bridge circuit and the galvanometer conductor 39 and resistors 41, 42 and 43 in series therewith connected across the other two apices of the bridge circuit. One of the arms on the positive battery side of the bridge includes the power supply conductor 27 and the portion of potentiometer 31 between that power supply conductor and the contact arm of potentiometer 31. The other arm on the same side of the bridge includes only the remaining portion of potentiometer 31 and resistor 30. The arm on the negative battery side of the potentiometer adjacent to that which contains power supply conductor 27 includes the pair of potential dividers 21 and 26 which are in parallel, the power supply conductor 28 and a portion of the potentiometer 32. The remaining arm of the bridge contains the remainder of the potentiometer 32, resistor 35 and the two potentiometers 36 and 37 which are in parallel. The circuit of galvanometer conductor 48 is open at the contact arm of the lower bank of the switch 33, so that no current will flow in this circuit. The circuit from contact arm 45 of potential divider 36 to contact arm 19 of potential divider 21 is open at the upper contact arm of switch 33 so that there will be no division of current in the potential divider 36.

With the apparatus thus arranged the contact

arm of potentiometer 31 is adjusted until the galvanometer 58 indicates zero current in the galvanometer conductor 39, which is an indication that the Wheatstone bridge circuit has been balanced. Thereupon the operator at the receiving station instructs the attendant at the transmitting station to move the crank wheel 18 to the setting 51, which is at the left-hand end of the winding of the potential divider. The operator at the receiving station moves the switch arms of switch 33 into engagement with the lower contacts. The effect of these two operations, the one at the transmitting station involving changing the position of potential divider contact arm 19 and the one at the receiving station involving switching of switch 33 is to transfer the set of potential dividers 21 and 26 and the set of potential dividers 36 and 37 out of the arms of the Wheatstone bridge circuits which receive negative battery and into the adjacent arms which receive positive battery, so that the two pairs of potential dividers have been moved from one side of the galvanometer circuit to the other side. Potentiometer 32 is then adjusted until the galvanometer 58 gives a zero reading.

Upon switching back to the first condition, namely, with potential divider contact arm 19 engaging the contact representing a reading of $50/100$ and switching the gang switch contact arms back to their upper contacts the first established balance may be found to have been disturbed, particularly if the adjustment of potentiometer 32 was substantial. The bridge circuit may be rebalanced by readjusting potentiometer 31. By this method of alternately rebalancing of the bridge circuit for the two different sets of connections, by means of potentiometers 31 and 32, a condition may be achieved in which no unbalance will appear upon switching from one to the other of the two bridge circuit conditions. Since the resistance of potential divider 21 is the same as that of potential divider 36 and the resistance of potential divider 26 is the same as that of potential divider 37, the over-all resistance of each parallelly connected pair of potential dividers is the same, and since transference of the two pairs of potential dividers from two arms of the bridge on one side of the galvanometer to the two arms on the other side does not disturb the balance of the bridge, it follows that the two arms on one side of the galvanometer conductor contain equal total resistance with or without the potential dividers and the two arms on the other side of the galvanometer conductor contain equal total resistance with or without the potential dividers. Were this not true, the insertion or removal of the pairs of potential dividers would alter the ratios between arms on either side of the galvanometer conductor and would unbalance the bridge. Accordingly, it follows that with the bridge circuit thus balanced the resistance of power supply conductor 27 plus the resistance of that portion of potentiometer 31 between conductor 27 and the contact arm of potentiometer 31 is equal to the resistance of the remainder of that potentiometer plus the resistor 30. Similarly, the resistance of power supply conductor 28 plus the resistance of that portion of potentiometer 32 between conductor 28 and the contact arm of potentiometer 32 is equal to the resistance of the remainder of that potentiometer plus resistor 35. The resistance of the power supply conductors 27 and 28 has thus been balanced at the receiving station and this balance

may be checked from time to time and balance restored if it is found that the resistance of power supply conductors 27 and 28 has changed materially. Upon completion of a balancing operation the switch arms of switch 33 are restored to the middle contacts of the three banks of contacts and the system is thus placed in condition for reproducing at the receiving station continuously varying readings of the optical device 11 at the transmitting station.

When the optical device 11 is trained on a distant moving object the movement of which is to be followed, the attendant at the transmitting station informs the operator at the receiving station over the supplemental telephone or telegraph system, hereinbefore mentioned, of the degree reading of the optical device 11, since the potential divider 26 and its companion potential divider 37 represent only a fraction of a full revolution of optical device 11, such as 30 degrees, as previously set forth by way of example. One revolution of potential divider contact arm 24, therefore, represents a sector corresponding to $\frac{1}{2}$ of a revolution of shaft 13 and the attendant at the transmitting station need inform the operator at the receiving station only as to the identity of the sector in which optical device 11 is disposed.

Assuming that at the time that the attendant at the transmitting station trains optical device 11 upon a moving object and begins to follow the movement of that object by rotating crank wheel 18, the contact arms of potential dividers 36 and 37 occupy random positions not corresponding to the contact arms of potential dividers 21 and 26, potential differences will be impressed upon the galvanometer conductors 39 and 48 which will cause galvanometers 38 and 47 and galvanometers 58 and 64 to be deflected from their zero positions. It is then incumbent upon the operator at the receiving station to rotate the contact arms of potential dividers 36 and 37, by means which will be described in detail hereinafter, to reduce the deflection of galvanometers 58 and 64 to zero. The operator can tell by the direction of deflection of the galvanometers in which direction the contact arms should be moved to reduce the deflection to zero, and the controlling means may be arranged so that operation thereof in the same direction as the galvanometer deflection will increase the deflection and operation in the opposite direction will reduce the deflection. As the contact arms of potential dividers 36 and 37 are brought into positions corresponding to those of the contact arms of potential dividers 21 and 26, the current in the galvanometer conductors 39 and 48 will be gradually reduced until the galvanometers read zero. The attendant at the transmitting station is presumably rotating crank wheel 18 continuously to keep the optical device 11 trained on the moving object and therefore is continuously unbalancing the system. However, the operator at the receiving station continuously moves the contact arms of potential dividers 36 and 37 in an attempt to maintain galvanometers 58 and 64 at zero readings and to the extent that the operator succeeds the contact arms of potential dividers 36 and 37 will be kept in substantial synchronism with the contact arms of potential dividers 21 and 26. The attendant at the transmitting station is informed at all times as to the actions of the operator at the receiving station with reference to potential dividers 36 and 37 because the galvanometers 38 and 47 are contained in the gal-

vanometer conductors 39 and 48 at the transmitting station and will indicate failure of the operator at the receiving station continuously to rebalance the system as the attendant at the transmitting station continuously unbalances it.

As long as the potential dividers at the receiving station are kept substantially in synchronism with those at the transmitting station there will be very little current flowing in galvanometer conductor 39 and an insufficient potential difference will be developed across resistance 43 to operate relay 57, so that the relay will remain deenergized. If the potential dividers at the receiving station lag slightly behind those at the transmitting station the current through resistors 41, 42 and 43 will be in one direction and galvanometer 58 will be deflected to one side whereas if the potential dividers at the receiving station lead those at the transmitting station slightly the current through the resistors 41, 42 and 43 will be in the opposite direction and the galvanometer 58 will be deflected in the opposite direction. Since the movement of contact arm 24 with reference to potential divider 26 is step by step and that of potential divider 37 is also step by step, as in the case of potential dividers 21 and 26, there is little likelihood of unbalance being indicated by galvanometer 64 after the two sets of potential dividers have been brought substantially into synchronism, except when either of the potential dividers 21 or 36 moves through the zero position and the other has not yet moved through the zero position due to a slight lag between them.

When the contact arm of potential divider 21 moves from the contact representing $\frac{50}{100}$ to that representing $\frac{51}{100}$ it leaves one end of the potential divider and moves into engagement with the opposite end. In so doing it goes directly from one battery polarity to the other. Assuming that the contact arm of potential divider 36 is lagging slightly and has not yet left the position corresponding to a reading of $\frac{50}{100}$ of a degree, the entire supply voltage will be impressed on the galvanometer conductor 39 and the current will be in the reverse direction to that previously existing because of the change in polarity at the contact arm of potentiometer 21, and a relatively large current will flow through resistors 41, 42 and 43 in the opposite direction to the small current previously flowing. The large potential difference thus developed across resistor 43 will operate polar relay 57 through rectifier 56 and the current through the relay will be in the same direction regardless of which end of resistor 43 is positive. Relay 57 becoming energized connects resistor 59 in series with galvanometer 58, and connects this series circuit across resistor 42 in the reverse direction relative to the previous connection of galvanometer 58 across resistor 41. With the current through resistor 42 now reversed and the connection of galvanometer 58 also reversed, the operator at the receiving station will continue to move the contact arm of potential divider 36 in the same direction that he had previously been moving it and in the specific example outlined herein, will move the contact arm across from the right-hand end of potential divider 36 to the left-hand end. Were it not for this reversal of the connection of galvanometer 58 the galvanometer would be deflected in the opposite direction upon the reversal of current through resistors 41, 42 and 43 which reversal the operator might in-

interpret as necessitating reverse rotation of the contact arm of potential divider 36 in order to restore balance. Such reverse movement would restore balance eventually from the standpoint of galvanometer conductor 39 but would unbalance the system from the standpoint of galvanometer conductor 48 because the backward movement of the contact arm 45 of potential divider 36 relative to that of potential divider 21 would also result in backward movement of the contact arm 50 of potential divider 37 relative to that of potential divider 26. With the reversing arrangement comprising rectifier 56 and relay 57 the operator receives no false indication when the potential divider contact arms move across the gap in the potential dividers. The series resistor 59 reduces the current through galvanometer 58 so that the galvanometer is not deflected off scale.

Galvanometer 54 has associated with it the same type of protective arrangement comprising the rectifier 61 and the polar relay 62 for preventing a false indication when the contact arm of one of the full degree registering potentiometers 26 and 37 moves across the gap of its potential divider ahead of the contact arm of the other. It is to be noted that the galvanometers 38 and 47 are not shown as being provided with a reversing and current reducing system consisting of a rectifier and relay operated thereby. They could be provided with such supplemental apparatus if desired but since in the normal mode of operation observations being made at the transmitting station are transmitted to the receiving station, so that the burden is upon the operator at the receiving station to follow the potential dividers at the transmitting station, the fact that the galvanometers 38 and 47 may on occasion deflect suddenly in the reverse direction and through a wide arc, is of no consequence because the attendant at the transmitting station is not ordinarily dependent upon indications of the galvanometers 38 and 47 for instructions as to the operation of potentiometers 21 and 26.

Occasions may arise, however, for operation of the system in the reverse direction. For example, it may be desired to instruct the attendant at the transmitting station to scan another area for an object or to train the optical device on another object, the general location of which with reference to the transmitting station, the operator at the receiving station is informed. Accordingly, the receiving station may instruct the transmitting station by telephone or telegraph as to the sector in which the scanning of an area for another object or in which the training of optical device 11 upon another object is to be done and the operator at the receiving station may then adjust the contact arms of the potential dividers 36 and 37 to positions representing the degree and hundredths of degree position at which scanning of an area for an object by means of optical device 11 is to be performed. Under these circumstances the operator at the receiving station will unbalance the system in so adjusting the potential dividers 36 and 37 and the attendant at the transmitting station will restore the system to balance by operation of crank wheel 18 in the direction which reduces the deflection of galvanometers 38 and 47, and when the system has been rebalanced the attendant can search carefully by means of optical device 11 for the distant object which is being called to his attention if he has not already found it.

Whereas Fig. 1 shows how the contact arms of potential dividers 21 and 26 may be operated manually, Fig. 4 shows a system for driving the contact arms of potential dividers 36 and 37 by means of a variable speed motor, with means for varying the speed of the motor so that when the optical device 11 is being rotated at a substantially uniform rate in following a moving object, the contact arms 45 and 50 of the receiving potential dividers 36 and 37 may be driven at the same uniform rate to continuously rebalance the potential divider system as it is continuously unbalanced at the transmitting station.

In Fig. 4 the contact arm 45 for the hundredths degree potential divider 36 is fixed to a shaft 76 which has secured thereto a worm wheel 77. Worm wheel 77 meshes with a worm gear 78 secured to a shaft 79 which has secured thereto a cross arm 81 which supports at the opposite ends thereof freely rotatable beveled planetary gears 82 and 83. Shaft 79 supports a sleeve 84 which has at one end a beveled gear 86 meshing with the planetary gears 82 and 83 and at the other end a worm wheel 87, the beveled gear 86 and worm wheel 87 being fixedly secured to sleeve 84.

Shaft 79 also supports a sleeve 88 which has secured to one end a beveled gear 89 meshing with the planetary gears 82 and 83 and which has secured to the other end a beveled gear 91. A beveled gear 92 in mesh with the gear 91 is secured to a shaft 93 which also has secured thereto a worm wheel 94 which meshes with a worm gear 96 secured to a shaft 97. Shaft 97 also has secured thereto a crank wheel 98.

A full degree potential divider 37 has its contact arm 50 fixed to a shaft 101. The shaft 101 has secured thereto a worm wheel 102 which meshes with a worm gear 103 secured to a stub shaft 104. Shaft 104 has secured thereto a worm wheel 106 which meshes with a worm gear 107 secured to a shaft 108. Shaft 108 has secured thereto a cross arm 109 which rotatably supports beveled planetary gears 111 and 112, which structure is comparable with the cross arm 81 and the planetary gears 82 and 83. Shaft 108 supports a sleeve 113 which has secured thereto at one end a beveled gear 114 and at the other end a beveled gear 116. Beveled gear 114 meshes with a companion beveled gear 117 secured to a shaft 118 which also has secured thereto a crank wheel 119. Beveled gear 116 meshes with the planetary gears 111 and 112. Shaft 108 also supports a sleeve 121 which has secured to the ends thereof beveled gears 122 and 123. Beveled gear 122 meshes with the planetary gears 111 and 112 and beveled gear 123 meshes with a beveled gear 124 secured to shaft 79.

Worm wheel 87 is in mesh with a worm gear 126 secured to the rotor shaft 127 of a variable speed electric motor 128. When motor 128 is operating it drives sleeve 84 through worm gear 126 and worm wheel 87 and thus imparts rotation to sleeve 84. There is a considerable gear reduction between shaft 127 and sleeve 84 so that the motor 128 may operate at a sufficient speed to have steady speed and driving characteristics while imparting very slow rotation to sleeve 84. The sleeve 84 in turn imparts rotation to beveled gear 86.

The pitch of worm gear 96 is such that in combination with the worm wheel 94 it constitutes a non-reversible drive, by which is meant that shaft 97 upon being rotated by crank wheel 98 will impart rotation to shaft 93 but that shaft 93

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cannot impart rotation to shaft 97 through the gears 94 and 96. Thus with shaft 93 held stationary due to the non-reversible characteristic of the drive, sleeve 88 and beveled gear 89 are held stationary through beveled gears 91 and 92. Beveled gear 86 in rotating causes planetary gears 81 and 82 to roll in engagement with stationary beveled gear 89 in accordance with the well known planetary or differential gear action and the planetary gears, in rolling against stationary gear 83 impart rotation to shaft 79 through cross arm 81. The speed of rotation of shaft 79 will be one-half the speed of sleeve 84 as is also well known in power transmitting mechanisms of this type so that a further speed reduction takes place in the planetary gear mechanism and a still further speed reduction occurs in the gearing comprising worm gear 78 and worm wheel 77 between shaft 79 and the hundreds potentiometer contact arm shaft 76.

Shaft 79 imparts rotation through beveled gears 123 and 124, through the planetary gear mechanism comprising beveled gears 122 and 116 and planetary gears 111 and 112, through shaft 108, gears 107 and 106, shaft 104, gears 103 and 102, and shaft 101 to the contact arm 50 of potential divider 37. Beveled gear 117 is provided with two diametrically opposed recesses 131, and a spring detent 132 engages one or the other of the recesses 131 and holds gear 114, sleeve 113 and gear 116 stationary so that planetary gears 111 and 112 roll against gear 116 in imparting rotation to shaft 108.

The speed reduction provided at the several points previously described between shaft 79 and shaft 101 is such that the contact arm 50 of potential divider 37 moves through the distance from one potential divider contact to another while the contact arm 45 of potential divider 36 rotates through a full revolution, which is comparable with the relative speeds of rotation of potential divider contact arms 19 and 24 in Fig. 1. It will be understood that the shaft 76 will be provided with the same time of cam and follower mechanism as that shown in Fig. 1 for causing the housing of potential divider 37 to move uniformly with its contact arm except when the contact arm associated with potential divider 36 is passing through its zero position in either direction, whereupon the housing of potential divider 37 will be shifted one way or the other with respect to its contact arm as is fully described in connection with Fig. 1. The cam and follower mechanism for shifting the housing of potential divider 37 has been omitted from Fig. 4 for the sake of simplicity.

If it is desired to operate the contact arms of potentiometers 36 and 37 manually instead of by the aided tracking mechanism comprising motor driven shaft 127, this may be accomplished by means of manually operable crank 98. The drive will be imparted through bevel gears 92 and 91, sleeve 88, bevel gear 89 and planetary gears 82 and 83 to shaft 79. The gearing comprising worm gear 126 and worm wheel 87 is a non-reversible drive similar to worm gear 96 and worm wheel 94, in the sense that shaft 127 cannot be rotated from sleeve 84, so that gear 86 will be stationary and planetary gears 81 and 82 will roll against it. Operation of shaft 79 by manual operation of crank 98 will probably be feasible only under the circumstance that very slow rotation of shaft 76 is required to keep the potential divider system balanced because there is a gear reduction between shafts 97 and 93, a 2 to 1 reduction between sleeve

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88 and shaft 79 through the planetary gear mechanism and a further reduction between shaft 79 and shaft 76 through worm gear 78 and worm wheel 77 so that it may not be possible to rotate shaft 97 sufficiently fast manually to cause shaft 76 to track with shaft 17 of Fig. 1 and keep the potential divider system balanced. Manual operation of shaft 17 in Fig. 1 is entirely feasible because crank 18 is directly secured to shaft 17, although it will be understood that power driven aided tracking mechanism similar to that shown in Fig. 4 may be employed if desired at the transmitting station shown in Fig. 1.

The speed of motor 128 is controlled by a magnetic drag unit associated with the rotor shaft 127 of motor 128 and controlled to vary the speed of the motor by the manually rotatable shaft 93. Shaft 127 of the motor has secured thereto a pair of spaced iron or iron alloy discs 136 and 137 that are permanently magnetized and are similarly oriented on shaft 127 from the standpoint of their magnetic poles. Between the magnetized discs 136 and 137 there is disposed a disc 138 of copper, aluminum or other non-magnetic metal. Preferably the axial aperture in disc 138 is sufficiently greater in diameter than shaft 127 that the disc does not engage the shaft and the disc may be supported by radially extending tension springs 139. It is also preferable that the thickness of disc 138 be less than the space between the magnetized discs 136 and 137 so that the disc 138 may be supported out of engagement with either of the discs 136 and 137 and no tendency to rotate shall be imparted to disc 138 by the discs 136 and 137 through frictional engagement.

Disc 138 has secured thereto an arm 141 preferably of insulating material, which has secured thereto an electrical contact block 142. On one side of contact 142 in a plane at right angles to the axis of shaft 127 is a contact 143 and on the other side is a contact 144 similar to the contact 143. Contacts 143 and 144 are so spaced that when disc 138 is freely supported by springs 139 without torque being applied thereto, contact 142 is about midway between contacts 143 and 144.

Disc 138 has opposed tension springs 146 and 147 connected to its arm 141. The remote end of spring 146 is connected to a fixed mounting 148 and the remote end of spring 147 relative to the arm 141 of disc 138 consists of or is connected to a flexible strand or cable which is wrapped several times around a sleeve 149 and has its free end secured to the sleeve. Sleeve 149 is supported by shaft 93 and has frictional engagement therewith so that when shaft 93 is rotated by means of crank 98 the tension upon springs 147 and 146 will be increased or decreased. Sleeve 149 has secured thereto a flange or disc 151 which is engageable by a flexible locking brake lever 152 which may be urged into engagement with disc 151 by means of the button-headed rod 153. Disc 151 is also provided with a laterally extending stop pin 154 which is engageable with a stop post 156 for limiting the rotation of sleeve 149 to substantially one revolution.

The magnetic drag unit comprising discs 136, 137 and 138 comprises a motor reversing and speed regulating mechanism. For this purpose motor 128 may be of the capacitor type, for operation on alternating current, having two field windings and a capacitor connected in delta arrangement. One side of the source of alternating current is connected to contact 142 supported by disc 138 and the other side of the source is connected to the apex of the two field windings

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of motor 128. The two fixed contacts 143 and 144 are connected to the other ends of the two field windings and thus also to the two sides of the capacitor.

Assuming that the apparatus is as shown in Fig. 4 with contact 142 engaging neither of the contacts 143 and 144, the circuit of motor 128 will be open so that shaft 127 will be stationary. Assuming that it is desired to start motor 128 running in clockwise direction as viewed at the left-hand end of shaft 127, crank wheel 98 is rotated in the direction to impart counter-clockwise rotation to shaft 93 as viewed from the left-hand end. This unwinds the cable which is connected to spring 147 and reduces the tension of that spring thereby permitting spring 146 to pull contact 142 into engagement with stationary contact 144. This causes the field of motor 128 to be energized to drive the shaft 127 in clockwise direction. As the magnetic discs 136 and 137 rotate in clockwise direction they impart a torque to disc 138 tending to rotate it in clockwise direction also and when this torque exceeds the force by which contact 142 is held in engagement with contact 144, which is the difference between the forces exerted by springs 146 and 147, contact 142 will be moved out of engagement with contact 144. This opens the circuit of motor 128 whereupon it begins to decelerate and the torque on disc 138 is reduced thus permitting it to return to engagement with contact 144. With a steady supply voltage for operating motor 128 a condition of substantial equilibrium will develop under which motor 128 will operate at a steady speed just below that which would cause contact 142 to move out of engagement with contact 144. The speed of the motor 128 may be increased by further rotating sleeve 149 in counter-clockwise direction to further decrease the tension of spring 147, whereby a greater torque will be required to disengage contact 142 from contact 144. Conversely, the speed of motor 128 may be decreased by rotating sleeve 149 in clockwise direction by means of crank wheel 98 to increase the tension of spring 147 so that a lesser torque is required to disengage contact 142 from contact 144.

If the motor 128 is to be driven in counter-clockwise direction sleeve 149 is rotated clockwise until contact 142 has been brought into engagement with contact 143. This completes the circuit of the motor for driving shaft 127 in counter-clockwise direction. The torque imparted to disc 138 then tends to move the disc in counter-clockwise direction. The speed may be increased by increasing the tension of spring 147 and may be decreased by decreasing the tension. It will be noted that this is the reverse of the method of increasing or decreasing the speed of motor 128 when it is driving shaft 127 in clockwise direction. Each time that the speed of motor 128 or its direction of operation is to be changed crank wheel 98 is rotated manually in the proper direction. Thereafter motor 128 will operate at constant speed under the control of the magnetic drag governor. With this arrangement the potential dividers 36 and 37 may be operated to keep the potential divider system continuously balanced and the galvanometers at zero deflection by manipulation of crank 98 after releasing brake 152, if the rate of change of position of optical device 11 under the control of crank 18 at the transmitting station is substantially uniform.

If potential dividers 36 and 37 are to be oper-

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ated manually with motor 128 not running, or if the speed of the motor has been adjusted to drive potential dividers 36 and 37 in unison with potential dividers 21 and 26 but there is a phase difference to be corrected, crank wheel 98 is rotated with pin 153 depressed to lock flange 151. Under either of these conditions the motor governor will not be disturbed while contact arms 45 and 50 are rotated manually. In the case of phase correction, the manual rotation will be in additive or subtractive relation to that being imparted by the driving motor.

Shaft 79 may be connected to and control a computing device for performing mathematical calculations based upon the changing position of the contact arms 45 and 50 of the potential dividers 36 and 37 necessary to keep the galvanometers at zero deflection. An understanding of the nature of such calculating device is not essential to an understanding of the present invention. However, it may be desirable to make visual observations based upon the changing positions of the contact arms of the potential dividers at the receiving station, such as for the purpose of plotting the course of movement of the object upon which the optical device 11 at the transmitting station is trained. Furthermore, since the potential divider contact arms 45 and 50 may be continuously moving and the movement of the contact arm 45 of potential divider 36 may be relatively rapid, it may be desirable to arrest the visual indicating means while readings are being taken without disturbing the continued movement of the potential divider contact arms. To this end shaft 76 has secured thereto a heart-shaped cam 161 the notch of which is at minimum radius and the point of which is of maximum radius, with the two halves of the periphery continuously decreasing in radius from the point to the notch of the cam. The portion of shaft 76 extending above heart-shaped cam 161 fits into a sleeve to which is secured a disc 162 and an indicator pointer 163 which cooperates with a fixed scale 164. Disc 162 has pivoted thereto a lever arm 165 which carries at its free end a depending pin 167 extending through slot 166 in disc 162. Lever arm 165 is biased by a tension spring 168 to urge lever arm 165 toward sleeve 165. Pin 167 carries at its lower end a roller 169 which engages the periphery of the heart-shaped cam 161. A normally disengaged friction brake lever 171 is operable into engagement with the periphery of disc 162 by means of push button 172 for arresting disc 162 and indicator pointer 163.

Upon the operation of brake 171 to arrest indicator pointer 163, with heart-shaped cam 161 continuing to rotate with the contact arm of potential divider 36, roller 169, rolling against the periphery of cam 161 will be moved outwardly from the axis of cam 161 as portions of the cam of increasing radius are presented to the roller, spring 168 yielding to permit the movement of the lever arm 165 as roller 169 is cammed outwardly. After the taking of a reading of the position of indicator pointer 163, friction brake 171 is released by releasing the pressure upon push button 172. Disc 162 is thus released and spring 168 which yielded to permit movement of roller 169 along portions of the periphery of cam 161 of increasing radius, causes roller 169 to roll along the periphery of cam 161 to the point of minimum radius, and roller 169, acting through pin 167 carries disc 162 around, with it thus restoring indicator pointer 163 to a definite angular posi-

tion in relation to cam 161 and thus to the contact arm 45 of potential divider 36, which has a fixed relation to cam 161. It will be apparent that roller 169 will return to the notch of cam 161 either clockwise or counter-clockwise depending upon which is the shortest route from the point engaged by the roller at the time that brake 171 is released. As shown in Fig. 4 the shaft 101 has a similar heart-shaped cam and roller mechanism for driving degree indicator pointer 176.

The crank wheel 119 and gear 117 afford means for adjusting the full degree potential divider 37 to add or subtract whole degrees under the circumstance that the potential divider 37 is considerably out of step with the potential divider 21 at the transmitting station. When crank wheel 119 is rotated it imparts rotation to shaft 108 through gears 117 and 114, sleeve 113, gear 116 and planetary gears 111 and 112. The gear ratios are such that rotation of crank wheel 119 through a half revolution moves the contact arm 50 of potential divider 37 through a distance corresponding to one degree, which is the distance from one contact to the next on the potential divider 37. This is the reason for the provision of the diametrically opposed recesses with which detent 132 cooperates. A correction of this sort may be effected while the shaft 79 is being driven from shaft 127 and corrections amounting to whole degrees will be added to shaft 101 if in concluding a correcting operation shaft 110 is brought to rest with detent 132 engaging one of the recesses 131, which is the correct procedure.

A modified transmission system is shown in Fig. 6. This system contemplates the provision of only one potential divider for representing instrument readings at the transmitting station and one potential divider for reproducing instrument readings at the receiving station. These potential dividers are arranged to represent hundredths degree values and correspond to the potential divider 21 in Fig. 2 and 36 in Fig. 3. As previously stated supplemental telephonic or telegraphic communication may be employed between the transmitting and receiving station and under certain circumstances such supplemental communication may be almost steady, so that it would be feasible to transmit whole degree information over the supplemental communication channel, leaving only the hundredths degree information to be transmitted under direct control of the optical instrument and registered by a single potential divider at the receiving station.

In Fig. 6 the reference numeral 201 designates the hundredths degree potential divider at the transmitting station and the reference numeral 202 designates the hundredths degree potential divider at the receiving station. Power supply lines 203 and 204 are connected to the end contacts of the potential divider 201 and extend to the receiving station where each is connected to one terminal of potentiometers 206 and 207, respectively. The potentiometers 206 and 207 correspond with the potentiometers 31 and 32 in Fig. 3 and serve to balance the resistance of the power supply conductors 203 and 204. The other ends of the potentiometers 206 and 207 are connected through resistors 209 and 210 to the two end terminals of receiving potential divider 202. The contact arms of balancing potentiometers 206 and 207 are connected to the terminals of a power supply battery 208 by means of which potential differences are impressed across the potential dividers 201 and 202, such potential differences being equalized by the potentiometers 206 and 207.

Potential divider 201 is provided with separate main and auxiliary contact arms or brushes 211 and 212, respectively, which engage diametrically opposite contacts of the potential divider, are insulated from each other, and are connected directly or by means of individual collector rings 213 and 214, respectively, to galvanometer conductors 216 and 217, respectively. The galvanometer conductors 216 and 217 include galvanometers 218 and 219, respectively, at the transmitting station and extend to the receiving station where they are connected to the back and front contacts, respectively, associated with the upper armature of a relay 221. The upper armature of the relay 221 is connected to one terminal of a galvanometer 222.

The potential divider 202 at the receiving station has main and auxiliary contact arms or brushes 223 and 224, respectively, which are connected directly or through individual collector rings 226 and 227, respectively, to the back and front contacts associated with the lower armature of relay 221. The lower armature of relay 221 is connected to the middle contact of the lower bank of a three-point multiple bank switch 228 which is used for the same purpose as the multiple bank switch in Fig. 3, namely for arranging bridge circuits for balancing the power supply conductors 203 and 204. The lower switch arm of switch 228 is connected to the other terminal of galvanometer 222. The upper and lower contacts of the lower bank of multiple bank switch 228 are connected to the two end terminals of potential divider 202. One terminal of relay 221 is connected to one terminal of battery 229, the other terminal of which is connected to the switch arm associated with the upper bank of switch 228. The middle contact of this bank is the only one having a connection and it is connected to one of two collector arcs associated with potential divider 202. The other of the two collector arcs 231 is connected to the other terminal of relay 224 and the two collector arcs are bridged by a brush 232 which is insulated from but moves with the diametrically opposed contact arms or brushes 223 and 224.

The power supply conductors 203 and 204 are individually balanced to produce equal potential differences across potential dividers 201 and 202 in the same manner as described in connection with Fig. 3, namely, by setting the main brush 211 on first one and then the other of the end contacts of potential divider 201 and moving switch 228 to one and then the other of the extreme positions. At the upper contact bank the circuit of relay 221 is interrupted so that the armatures are released to their back contacts, thus opening the galvanometer conductor 217 and connecting galvanometer conductor 216 through galvanometer 222 to the switch arm associated with the lower bank of switch 228. By means of this switch arm the galvanometer 222 is connected first to one and then to the other of the end terminals of potential divider 202, the effect of which is to switch the full resistive circuit of potential divider 202 from one to the other of two arms on opposite sides of the galvanometer conductor. These switching operations are coordinated, by means of telephonic or telegraphic communication, with the movement of the main brush 211 of potential divider 201 from one to the other of the two end contacts of that potential divider, the effect of which is to switch the entire resistive circuit of the potential divider from one to the other of the two remaining arms

of the bridge circuit on opposite sides of the galvanometer conductor.

After the power supply conductors have been balanced switch 228 is restored to the middle contacts. Thereafter the potential divider 202 may be operated to continuously rebalance the potential divider system by keeping galvanometer 222 at zero deflection as the system is continuously unbalanced by the operation of potential divider 201. When the contact arms or brushes of potential divider 202, in operating, are in such positions that the brush 232 is out of engagement with the conductive arcs 231, the circuit of relay 221 is open and the galvanometer circuit is traced from the main brush 223 of potential divider 202 through the inner collector rings 226, the back contact and lower armature of relay 221, the middle contact and switch arm of the lower bank of switch 228, the galvanometer 222, the upper armature and back contact of relay 221, galvanometer conductor 216 including galvanometer 218 to the inner collector ring 213 of potential divider 201 and thence to the main brush 211 of that potential divider. However, when brush 232 moves into bridging relation to the conductive arc 231 it completes the energizing circuit for relay 221 and the galvanometer circuit is then traced from the auxiliary brush 224 of potential divider 202 through the outer collector ring 227, the lower front contact and armature of relay 221, the middle contact and switch arm of the lower bank of switch 228, galvanometer 222, the upper armature and front contact of relay 221, galvanometer conductor 217 including galvanometer 219 to the outer collector ring 214 of potential divider 201 and thence to the auxiliary brush 212. From this it will be apparent that neither of the brushes of potentiometer 202 has control of a galvanometer circuit when it is approaching or passing over the end contacts of the potentiometer, and assuming that potentiometer 202 is closely tracking potentiometer 201, which is a normal mode of operation, neither of the brushes of potentiometer 201 will have control of a galvanometer circuit when it is approaching or passing over the end contacts of that potentiometer. It follows from this that no relatively large potential of reverse polarity is ever suddenly impressed on a galvanometer conductor, for the avoidance of which the rectifier and relay circuits were provided in the system shown in Fig. 3. As distinguished from the system shown in Figs. 2 and 3 the system shown in Fig. 6 provides that the galvanometer deflection at the transmitting station shall always correspond in direction and magnitude with the galvanometer deflection at the receiving station, this being accomplished by switching from one to the other of the galvanometers 218 and 219 under the control of relay 221 at the receiving station. The system shown in Fig. 6 is therefore more readily adapted to transmission in the reverse direction under the circumstance that the receiving station wishes to instruct the attendant at the transmitting station to scan a particular area or train the optical device on a distant object of which the operator at the receiving station has knowledge.

The electrical system of Fig. 6 comprising only one potential divider at each station for instrument reading transmission may employ the same mechanical operating mechanisms as the electrical system shown in Figs. 2 and 3. For example, in Fig. 1 the potential divider 201 would be substituted for the potential divider 21 and the

potential divider 26 would be omitted together with its driving gear and shaft 22 and 23, respectively, and its shifting cam and follower mechanism including cam 27, bell crank 29 and link 32. At the receiving station, referring to Fig. 4, the potential divider 202 of Fig. 6 would be substituted for the potential divider 36. Potential divider 37 would be omitted together with cam and follower mechanism for shifting it in the manner shown in Fig. 1. However, shaft 101 and the heart-shaped cam and roller mechanism for driving indicator pointer 176 may be retained, because although the attendant at the transmitting station will inform the operator at the receiving station from time to time by telephone or telegraph as to the whole degree reading of the optical device 11, it is advisable to have both the degree and hundredths degree indicators at the receiving station so that the receiving station has a complete register of the reading of the optical device 11 which is continuously correct as long as the attendant at the transmitting station is following a particular moving object and makes no sudden and substantial change in the position of optical device 11, with which the operator at the receiving station may be unable to keep the shafts 76 and 101 synchronized. In this connection it may be mentioned that optical instruments of the type shown in Fig. 1 are sometimes provided with means for disengaging the driving worm 16 from the driven worm wheel 14 whereby the optical device may be swung through a wide angle without any accompanying rotation of shaft 17. Under such circumstances, it would be necessary for the attendant at the transmitting station to inform the operator at the receiving station as to where the indicator pointer 176 should be set to register correctly the degree reading of optical device 11. The operator can then bring the hundredths degree indicator pointer 163 into the correct position by balancing the potential divider system so that the galvanometer 222 will show zero deflection.

It has been set forth previously that the potential divider 37 represents only a part of a revolution of optical device 11 such as 30 degrees, for the reason that it may not be feasible to provide potential dividers having 360 contact points to represent in one revolution of its contact arm a full revolution of optical device 11. However, when a system of the type shown in Fig. 4 employs no potentiometer for full degrees corresponding to potential divider 37 the scale with which indicator pointer 175 cooperates may be graduated to indicate 360 degrees and such gearing may be employed between shaft 79 and shaft 101 as to cause shaft 101 to execute one revolution for 360 revolutions of shaft 76. Thus the pointers 163 and 176 will give direct readings of the positions of optical device 11.

Although certain specific embodiments of the invention have been shown in the drawings and described in the foregoing specification, it will be understood that the invention is not limited to such specific embodiments but is capable of modification and rearrangement without departing from the spirit of the invention and within the scope of the appended claims.

What is claimed is:

1. In a measuring system, a potential divider, means for adjusting said potential divider according to the characteristic to be measured, a second potential divider, means for adjusting said second potential divider, a common source of potential for said potential dividers, a galvanometer

conductor extending between said potential dividers, a galvanometer associated with said conductor for indicating disparity between the adjustments of said potential dividers, and automatically operable means for limiting the current through said galvanometer when said conductor receives opposite extremes of potential from said potential dividers.

2. In a measuring system, a potential divider, means for adjusting said potential divider according to the characteristic to be measured, a second potential divider, means for adjusting said second potential divider, a common source of potential for said potential dividers, a galvanometer conductor extending between said potential dividers, a galvanometer associated with said conductor for indicating disparity between the adjustments of said potential dividers, and automatically operable means for reversing the flow of current through said galvanometer and for limiting said current when said conductor receives opposite extremes of potential from said potential dividers.

3. In a measuring system, a potential divider, means for adjusting said potential divider according to the characteristic to be measured, a second potential divider, means for adjusting said second potential divider, a common source of potential for said potential dividers, a galvanometer conductor extending between said potential dividers and having a plurality of resistors in series therein, a galvanometer, a relay for connecting said galvanometer in shunt with either of two of said resistors in opposite polarity relationship, and a rectifier in shunt with another of said resistors for supplying energizing current for said relay irrespective of the direction of flow of current through said conductor when said conductor receives opposite extremes of potential from said potential dividers.

4. In a measuring system, a potential divider, means for adjusting said potential divider according to the characteristic to be measured, a second potential divider, means for adjusting said second potential divider, a common source of potential for said potential dividers, a galvanometer conductor extending between said potential dividers, a galvanometer for indicating disparity between the adjustments of said potential dividers, means for reversing the connective association of said galvanometer with said conductor, and means associated with said conductor for operating said reversing means irrespective of the direction of current through said conductor when said conductor receives opposite extremes of potential from said potential dividers.

5. In a signaling system, a station having a potential divider, means for adjusting said potential divider in accordance with information to be transmitted, said potential divider having a pair of diametrically opposed electrically independent contactors rotatable in unison, a second station having a potential divider, said potential divider having a pair of opposed electrically independent contactors rotatable in unison, means for adjusting the potential divider at said second station, a pair of conductors extending between said stations and interconnecting said potential dividers, means at one of said stations for supplying a source of potential between said conductors, a pair of galvanometer conductors extending between said stations, a galvanometer at said one station connectable to one galvanometer conductor and to one of the contactors of the potential divider at said station or to the other gal-

vanometer conductor and the other potential divider contactor, automatically operable means for connecting said galvanometer to one or the other of said galvanometer conductors and said contactors in accordance with the positions of said contactors for protecting said galvanometer from opposite extremes of potential at said potential dividers, and a pair of galvanometers at said other station each having one terminal connected to one of said galvanometer conductors and each having the other terminal connected to one of the potential divider contactors at said other station.

6. In a signaling system, a station having a potential divider, means for adjusting said potential divider according to information to be transmitted, a second station having a potential divider, means for adjusting the potential divider at said second station, a galvanometer conductor extending between said potential dividers, a galvanometer associated with said conductor for indicating disparity between the adjustments of said potential dividers and automatically operable means for protecting said galvanometer from opposite extremes of potential at said potential dividers.

7. In a signaling system, a station having a potential divider, means for adjusting said potential divider in accordance with information to be transmitted, a second station having a potential divider, means for adjusting the potential divider at said second station, a galvanometer conductor extending between said potential dividers, a galvanometer associated with said conductor for indicating disparity between the adjustments of said potential dividers and automatically operable means for limiting the potential difference applicable to said galvanometer to a safe value substantially less than the opposite extremes of potential at said potential dividers.

8. In a signaling system, a station having a potential divider, means for adjusting said potential divider in accordance with information to be transmitted, a second station having a potential divider, means for adjusting the potential divider at said second station, a galvanometer conductor extending between said potential dividers, a galvanometer associated with said conductor for indicating disparity between the adjustments of said potential dividers and automatically operable means for precluding the application to said galvanometer of the opposite extreme of potential at said potential dividers.

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