My invention relates to a scheme for indicating or controlling and thereby determining at a distance, various factors in connection with the operation of apparatus; and especially for the indication and control of such factors as are not readily ascertained or controllable adjacent the apparatus. For example, with the aid of this invention, the condition of a valve controlling the passage of fluid may be ascertained and/or controlled at a distance from the valve. Again, other conditions of the flow of the fluid can also be indicated, recorded and controlled at the distant point.

It is accordingly one of the objects of my invention to provide a simple and inexpensive apparatus with which these results may be accomplished.

In my form of system, use is made of an electric circuit, the characteristics of which are varied in accordance with, or as a function of, the variation in the apparatus to which my system is accessory. Indicating and controlling systems utilizing electric circuits have of course been suggested prior to my invention; but it is customary to make and break electric circuits in such systems. With the aid of my invention the making and breaking of electric contacts, with their attendant disadvantages, are largely or entirely obviated. Accordingly, it is another object of my invention to make it possible to control a distant indicator or a distant apparatus thru the medium of a controlling electric circuit in which there is no making or breaking of contacts.

In the present form of such electrical systems the indicating or controlling effect is so dependent upon the voltage and/or frequency of the current supplied that fluctuations thereof impair the precision of the device. It is an important object of my invention therefore to provide a system which is substantially free of error regardless of inconstancies in the actuating current.

It is an object of my device to indicate, totalize, record, and/or control the positions of members movable both manually and automatically, by the aid of a balanced impedance circuit in which the movement of the several devices is independent of variations in the current frequency and voltage.

It is a further object of my invention to apply the aforesaid system as to gage, indicate, and/or control a variable physical quantity, such as fluid flow for example, in such a manner that the indication and control may be selectively varied from fully automatic thru semi-automatic to entirely manual.

My invention possesses other advantageous features, some of which with the foregoing will be set forth at length in the following description, and in the drawing accompanying and forming part of the present specification. I have suggested but a few embodiments of my invention, but I desire not to be limited thereto, since the invention as defined in the claims may also be embodied in other forms, to the accomplishment of other objects dependent upon the particular use to which my invention is put.

Referring to the drawing:

The figure is a schematic plan of one embodiment of my invention as applied to the indication and control of liquid flow in a conduit.

In terms of broad inclusion the device of my invention comprises a translating device having a plurality of impedances which may be connected in parallel to a source of potential. Movable impedance varying elements or impedance variators are connected to movable members or bodies the state or condition of one of which is to be determined. A detector is provided which may be connected by suitable selective switches to respond to electrical differences as of current or voltage, across any two of the variable impedances, and this serves to indicate when the branches of the circuit are balanced. Since a balanced condition of the circuit is dependent upon equivalence of the impedances and therefore upon the relative positions of the movable impedance variators, it follows that a definite positional relation will exist between these movable variator elements whenever a balanced condition of the circuit is produced. Thus any movement or position of one member may be evaluated...
with respect to or translated to the other member by merely moving the said other member until the detector indicates a balanced circuit.

The parallel arrangement of the circuits is the preferable but not the only possible one. For example, the impedances may be arranged in series and the detector may be connected across two impedances to indicate difference in potential between them; i.e., the detector would be shunted on to a series circuit. The detector might then be replaced by one or more galvanoscopes or galvanometers.

Both motor driven and manually controllable means are provided for moving two of the movable members, and the detector is constituted as a relay which may be made to automatically control these motors in response to an unbalanced condition of the circuit. Thus the device is subject to either manual or automatic operation.

My translating device is herein applied to gaging, indicating, recording, totaling, and/or controlling the variable flow of a fluid thru a conduit. The conduit is provided with a flow meter, an indicator, a recorder, a totalizer, and a gate valve, each of which has its movable member connected to one of the impedance variators for varying the corresponding impedance.

By proper manipulation of the switches controlling the various impedances and motors, the indicator may be made responsive to either the meter reading or the gate valve position; and the gate valve position may be made responsive to either manual control thru the indicator member, or automatic control in response to movement of the movable flow meter member.

My invention deals also with variations of this system, but I will describe and illustrate in detail an embodiment of my invention as applied to gaging and controlling the flow of a fluid thru a conduit. It should be noted however that the lessons taught are applicable to variables other than flow, and may be applied for example to gaging, indicating, recording, totaling, and/or controlling variations in movable bodies, machine members, and operations.

As applied to a conduit 2, my invention is a device for gaging, indicating, and controlling flow thru the conduit.

Gaging means are provided and take the form of a flow meter 3 of the Venturi type including the Venturi tube 4. Leads 6 and 7 from the Venturi tube extend to the tops of chambers 8 and 9 of the modified manometer 11. These two chambers are closed from the outside atmosphere, and the connection between them is sealed by a pool 12 of mercury or the like. The inner chamber 9 is provided with a depending closed tube 13, the open upper end of which projects above the mercury level in the chamber. This tube forms a slide-way for the movable element or variator 14 of a variable impedance 16. This variator is sustained by a mercury float 17 constituting the movable member of the flow meter, and projects down partially into the field of an impedance coil 18 surrounding the tube 13. The variator 14 is of magnetic material and comprises a core armature for the impedance coil. This armature concentrates the flux in the coil and therefore multiplies its inductance. As the core is allowed to descend further into the coil, the proportion of iron to air in the impedance coil increases and causes a proportionate increase of this inductive form of reactive impedance. Thus coil 18 with its core 14 constitutes a variable inductive reactance component of impedance 16. A source 19 of fluctuating or alternating current, herein conveniently represented as a transformer, is connected to the circuit containing the coil.

Flow of fluid thru the venturi causes a pressure differential between chambers 8 and 9 proportional to a function of the flow and thereby causes a proportional variation in the mercury levels. The mercury float 17 will rise or fall in response to this variation and will thereby position the core 14 relative to coil 18 to vary the impedance of the circuit as a function of the float motion. Correspondingly the flow of current in each branch varies as a function of the change in impedance. Thus mechanical movement of float 17 is translated into variation of an electric current, by being made to alter the impedance to flow of current thru the circuit.

It is recognized that meters of other than Venturi type, and that meters, gages and, in general, measuring instruments of practically all types will be similarly utilized, depending upon the character of the variable quantity to be measured.

Means are provided at any convenient point, which may be at a distance, for converting this electrical variation into mechanical movement. A second impedance coil 21 preferably equal to coil 18 may be connected in parallel with it. One lead from each impedance coil passes through one of the magnetically opposed coils of a generator 22, to a common juncture with the other power supply lead; thus placing the impedance coils in parallel through detector 22. This coil 21 is part of the variable impedance 23. With the switch in the position shown by the solid lines in the figure, current from one wire 24 of the source is lead by a wire 26 to the detector 22, thru which it divides to the impedances coils 18 and 21. The other wire 25 of the source leads directly to the other terminal of coil 21, and a wire 20 connects the coil 18 to this wire of the source. A variator 27, here shown similar in all respects to armature 14, forms the core armature of coil 21, and with
it comprises the variable inductive reactance component of impedance 23. This core 27 is attached to a movable member 28 by a non-magnetic bar 29. The movable member has a threaded bore cooperating with a screw shaft 31 and is provided with a pointer 32 for an indicator scale 33. A hand-wheel 34 on the shaft 31 provides for manual movement of the member and its attached armature.

The purpose of the detector is to guide an operator, which may be human or mechanical, in his or its movement of the one movable member into a position corresponding to that of the other movable member; and in simplest form may be merely a device such as a galvanometer or telephone receiver, for indicating difference in potential across the parallel branches of the circuit, formed for example, by impedances 16 and 23. In the form illustrated, it is a magnetic pendulum armature 36, pivotally suspended between two solenoids 37 and 38. The terminals of the solenoids 37 and 38 and the armature 36 are connected to the impedances 16 and 23 by wire 39, switch 41, and wire 42, and by wire 43, switch 41, and wire 46 respectively. The other terminals 47 or 48 of each solenoid leads thru the common wire 26 to wire 24 of the source of current. Thus when the potential across the two branches of the circuit is different, unequal current will flow thru the two solenoids and consequently the pendulum will be attracted to one or the other solenoid. Its movement will direct the operator to turn shaft 31 in one direction or the other, thus moving the core 27 to equalize the two impedances and re-establish equilibrium in the circuit.

It will be seen that the position of movable member 17 of the meter may thus be translated to the indicator pointer 32 on movable member 28, and will indicate the condition of flow gaged by the flow meter. The accuracy of this translation is independent of variations in the voltage of source, because at the time of indication, the two impedances 16 and 23 are equal and since they are in parallel any variation in voltage will effect both equally. The device merely equalizes the current passing thru both branches of the circuit. It does not make any difference what the absolute value of the current passing thru each branch is. The accuracy of this translation is similarly independent of the frequency of the current supplied, because the reactance component of the two impedances is also equal.

It has been assumed that the resistances of the two parallel branches are equal, since equal coils are described.

The translation described is produced without the making and breaking of electric circuits, such as would be necessary if the movable armature were replaced by a sliding contact which varied the effective number of turns of a coil.

The movements of the cores 14 and 27, which for convenience may be regarded as subjective and objective respectively, need not be identical nor even proportional, but may be made any convenient function of each other by providing an unequal number or positioning of turns in the two impedances or by varying the cross sections of one or more of the cores. For instance, the formula representing the relationship between Venturi head and the flow of liquid or gas thru a Venturi tube is very complex, but the objective core may be made to assume a position proportional to the rate of flow thru the Venturi tube, while the subjective core assumes a position proportional to the Venturi head.

It is understood that the variable inductive reacances may be replaced by similar variable capacity reactances, i.e., the impedance coils and variatators may be replaced by variable condensers, to the accomplishment of the same result; and that various combinations of the known forms of impedance may be utilized. The movable armature could of course be replaced by a movable coil or by a sliding contact which varies the effective number of turns in the coil.

Automatically controlled power driven means are provided for moving the indicator pointer 32 and its associated parts. An electric motor 49 is connected to drive the screw shaft 31. Lead 51 connects the motor directly to one wire 26 of the source of current, the other wire 24 of which is connected thru lead 26 to the pendulum 36 of the detector 22. The pendulum is formed as a switch, and in its extreme position it is adapted to contact with either conductor 52 or 53, which lead in the position shown in the figure, thru a switch 54 to wires 56 or 57 to drive the motor 49 in opposite directions. When the circuit becomes unbalanced, the pendulum switch 36 will be attracted by one or other of its solenoids, and will complete one of two circuits thru the indicator motor 49 to actuate it in one direction or another. The detector 22 therefore constitutes a relay, or more specifically a detector-relay, for controlling motor 49, thereby automatically directing the movement of movable member 28.

In addition to the indicator pointer 32 the movable member 28 is provided with a pen 58 which cooperates with a clockwork driven disc 59 to form a recorder. A totalizer is also provided, and consists of another clockwork driven disc 61. The discs are driven at constant speed by clockwork mechanisms 62 and 63 which may be of well known type. The disc 61 drives a friction wheel 64 which is coupled to a revolution counter 66. The friction wheel is journaled in the movable member 28 in such manner that its distance off center of the disc, and therefore its amount of rotation, will be proportional to the position of the indicator.
One of the embodiments of my invention contemplates the physical control of a variable quantity for which gaging means have been described. This controlling means is herein constituted as a gate valve 67 for controlling the flow of fluid thru the conduit 2. A motor 68 is provided with suitable driving gear 69 for opening and closing the valve and may be connected to the source of current for operation at will thru the reversing switch 71. This switch connects to motor leads 72 or 73 for opposite directions of rotation. Connection to the source of current is made by a lead 74 to wire 24 of the source, and leads 76 and 20 from the motor to wire 28 of the source.

This controlling means is coordinated into my system electrically in much the same manner as the indicating means already described. The stem 77 of the gate valve 67 constitutes a movable body to which is attached a variator 80, preferably similar to the movable armature cores 14 and 27. A coil 78, preferably equal to coils 18 and 21, operates with this movable core 80 to form an inductive reactance component of impedance 79. Leads 81, 76, and 20 connect a terminal of the coil to wire 28 of the source of current, and lead 82 connects to switch 41. This switch provides selective means by which any two of the three coils: 78 of the controlling means, 18 of the gaging means, and 21 of the indicating means may be connected in parallel across the detector 22.

When switch 41 is turned to the position shown by the dot and dash lines in the figure, coils 78 and 21 will be connected in parallel across the detector so that the positions of the indicator pointer and gate valve may be kept in correspondence.

It is recognized that movable bodies other than valves may be similarly incorporated into the system. I have disclosed for indicating their position or directing their adjustment and that these purposes may be directed independently to a movable body as well as to gaging or controlling some dependent variable function such as fluid flow.

In combination with hand-wheel 34 and motor 68, the detector-relay 22 constitutes means for semi-automatically adjusting the position of the gate valve with its associated core. When the switch 54 is in a position opposite to that shown by the figure, it will contact with leads 84 and 86 instead of leads 56 and 57, and will therefore cause the relay to control the gate valve motor 68 thru its reversing leads 72 and 73 instead of controlling the indicator motor 49 thru its reversing leads.

Thus it will be seen that when switch 41 is turned to the position shown by the dot and dash lines in the figure so that the impedances 23 and 79 are in parallel, the position of the valve may be adjusted by merely actuating the hand-wheel 34 until a scale on the indicator indicates a proper valve opening. Under these conditions the indicator takes on the added function of an actuator. The principle of operation will be understood from the foregoing description. Adjustment of the indicator-actuator hand-wheel 34 will move the core 27 to vary the impedance 28, causing more or less current to flow thru this branch of the circuit. Detector-relay 22 will respond to this unbalanced condition by energizing the valve motor 68. This motor will position the valve as desired and will thereby move core 80 attached to the valve to vary impedance 79 until equilibrium is re-established in the circuit.

When the switch 41 is in the position illustrated by the dotted lines in the figure, so that impedances 16 and 79 are in parallel, the device acts as a full-automatic controller. The movable element of the flow meter will then be connected thru detector-relay 22 to control the valve by means of motor 68. The principle of operation is identical with that described when the flow meter and indicator are connected together, the motor 49 being merely replaced in the circuit by the motor 68. When flow becomes inconstant, due to variations in pressure or the like, the flow meter will respond to vary the impedance in its branch of the circuit, causing detector-relay 22 to initiate the operation of the gate valve motor 68 to readjust the flow.

It will be understood that other than electric motor means may be provided for actuating the movable members. For example, motor 68 could be replaced by a hydraulic motor having solenoid-controlled valves.

Means are provided for adjusting, calibrating, and balancing the system, and are shown in simplest form. An adjustable screw connection 87 is provided between the movable member 77 of the gate valve and movable armature core 80 of coil 78, and a similar connection 88 is provided between core 27 and movable member 26 of the indicator-actuator assembly. Adjustable resistances 89 and 91 are included in series with the coils 78 and 18 and permit balancing the resistances in the several branches of the circuit. It is contemplated that other and more refined adjusting and calibrating means may be provided where the addition is warranted and that adjustable inductances and capacities be added in series with the resistances when desired.

Where occasion dictates, the inductance of the several branches of the circuit may be unequal and either be balanced by other impedance factors or allowed for in the galvanometer reading, a galvanometer then replacing the detector or galvanoscope shown herein. This however, unless special precaution is taken, will make the accuracy of the device dependent upon constancy of frequency or voltage and is not therefore generally advis-
able. In general, such an expedient would be resorted to only where approximate readings are desired and expenditure of the time required to initially balance up the system is unwarranted. Such a condition might arise where a large number of objective and subjective impedances, of the type of impedances 16, 23, and 79, are included in a single circuit, and it is desired to rapidly switch from one to another to determine a plurality of variables.

I have described in simple form one of the many embodiments which my fundamental invention obviously suggests, but it is contemplated that the same may be applied in many combinations to the accomplishment of the same useful objects and may be modified to considerable degree without departing from the fundamental inventive concept.

Thus, for example, I contemplate so interconnecting and pluralizing the described elements that the several results herein set forth independently may be accomplished simultaneously, and with other measurements, indications, and controls as well as with those for fluid flow.

Due to the difficulties of exact expression, I will define certain of the terms used in the claims as follows:

1. The word "determine" is used in the sense of indicating, evaluating, or controlling of variables.

2. By the word "direct" I mean to point out or guide, regulate, govern.

3. For convenience of description the movable members 17, 28, and 77 and their associated parts will be qualified by the terms "subject" and "object" as they are used in the different connections above set forth.

4. For example, when the device is applied to indicating the position of the gate valve, the indicator will be the objective member; i.e., it will constitute the object of translation, while the gate valve will be the subjective member; and when the device is applied to the remote control of a valve this first-mentioned member may constitute the subject and the gate valve the object of translation.

I claim:

1. In an indicating and controlling system, a gaging means and a source of electrical potential, an impedance associated with and variable by the gaging means in proportional relationship thereto, a second impedance associated with control means for the system and variable in proportional relationship to the position thereof; a third impedance associated with indicating means for the system and variable in proportional relationship to the position thereof; means for detecting the relative magnitudes of a selected plurality of said impedances; means for connecting said plurality of impedances to the detecting means, and means controlled by the detecting means for controlling the position of the control means or for controlling the position of the indicating means depending upon the plurality of impedances selected.

2. In an indicating and controlling system having means for controlling the flow of material and means for metering said flow, gaging means for controlling the control means, an impedance associated with and variable by the gaging means in proportional relationship thereto, a second impedance associated with the control means and variable in proportional relationship to the position thereof; a third impedance associated with the metering means and variable in proportional relationship to the position thereof; means for detecting the relative magnitudes of the gaging means impedance and the control means impedance or of the gaging means impedance and the metering means impedance; means for connecting said impedances to the detecting means, and means controlled by the detecting means for controlling the position of the control means or metering means.

3. In an indicating and controlling system having means for controlling the flow of material and means for metering said flow, gaging means for controlling the control means; an impedance associated with and variable by the gaging means in proportional relationship thereto; a second impedance associated with the control means and variable in proportional relationship to the position thereof; a third impedance associated with the metering means and variable in proportional relationship to the position thereof; means for detecting the relative magnitudes of the gaging means impedance and the control means impedance or of the gaging means impedance and the metering means impedance; means for connecting said impedances to the detecting means, and means controlled by the detecting means for controlling the position of the control means or metering means, and means for manually controlling the position of the control means independent of said detecting means system.

4. In combination with a conduit for carrying a fluid, means connected with the conduit and including a movable gage element for gaging the flow of said fluid, means including a movable gate interposed in the conduit for controlling the flow of said fluid, means for manually adjusting the position of said gate, an indicator having a movable indicating element, means for manually adjusting the position of said indicating element, an electric circuit, a source of alternating electric potential impressed on said circuit, a plurality of inductance coils in the circuit, a magnetic core connected for movement with the gage element and movable within one of said coils to vary its inductance, a second magnetic core.
connected for movement with the gate and movable within another of said coils to vary its inductance, a third magnetic core connected for movement with the indicating element and movable within still another of said coils to vary its inductance, a translating device in said circuit and comprising a detector-relay responsive to differences in potential, a switch interposed in said circuit for selectively connecting any two of said coils in parallel thru the detector-relay; motors drivably connected with the indicating element and gate and actuated by the detecting means for optionally shifting the indicating element in ratio to movements made by the gate element, or shifting the indicating element in ratio to adjustments made in the position of said gate, or moving the gate in ratio to movements made by the gage element, depending upon the pair of coils selected for connection thru the detector-relay; and a second switch in said circuit for conditioning the detector-relay to actuate the gate driving motor for moving the gate in ratio to adjustments made in the position of the indicating element.

5. In combination with a conduit for carrying fluid, means connected with the conduit and including a movable gage element for gaging the flow of said fluid means including a movable gate interposed in the conduit for controlling the flow of said fluid, means for manually adjusting the position of said gate, an indicator having a movable indicating element, an electric circuit, a source of alternating electric potential impressed on said circuit, an impedance in said circuit and variable by the gaging means in proportional relation to changes in the position of said gage element, a second impedance in said circuit and variable by the control means in proportional relation to changes in the position of said indicating element, means for manually adjusting the position of said gate, an indicator having a movable indicating element, means for manually adjusting the position of said indicating element, an electric circuit, a source of alternating electric potential impressed on said circuit, an impedance in said circuit and variable by the gaging means in proportional relation to changes in the position of said gage element, a second impedance in said circuit and variable by the control means in proportional relation to changes in the position of said gate, a third impedance in said circuit and variable by the indicating means and in proportional relation to changes in the position of said indicating element, means connected in said circuit for detecting the relative magnitudes of a selected plurality of said impedances, means for connecting said plurality of impedances to the detecting means; drive means interposed in said circuit and actuated by the detecting means for optionally shifting the indicating element in ratio to movements made by the gage element, or shifting the indicating element in ratio to adjustments made in the position of said gate, or moving the gate in ratio to adjustments made in the position of the indicating element.

7. A device for determining the position of a movable element to be controlled comprising an indicator having a movable indicating element, an electric circuit, a source of alternating electric potential impressed on said circuit, a pair of impedances in said circuit, means connected for movement with the element to be controlled for varying the magnitude of one of said impedances, means connected for movement with the indicating element for varying the magnitude of the other of said impedances, means for moving the element to be controlled, means for moving the indicator element, and means interposed in said circuit and responsive to differences between the magnitudes of said impedances for directing movement of either one of said elements when the other is moved.

In testimony whereof, I have hereunto set my hand.

LEON H. CHAMBERLAIN.