Nov. 25, 1941. LE ROY C. PASLAY 2,264,098

DEFLECTION LIMITER FOR GALVANOMETERS

Filed Nov. 3, 1937

Fig. 1.

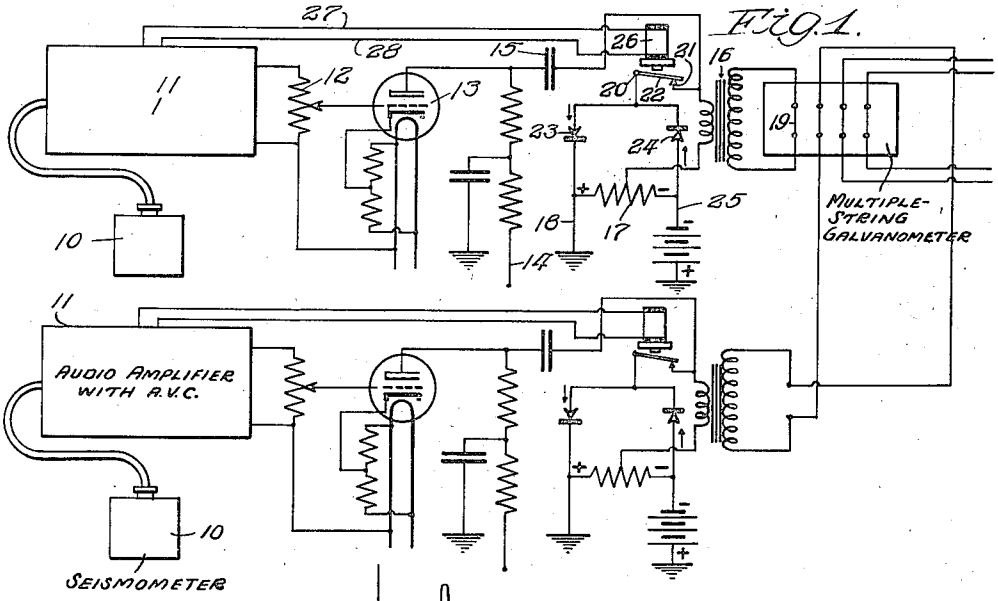


Fig. 3.

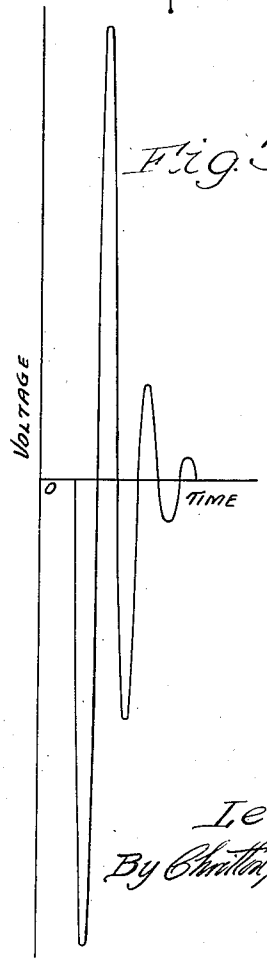


Fig. 2.

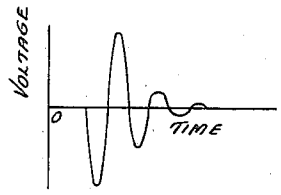
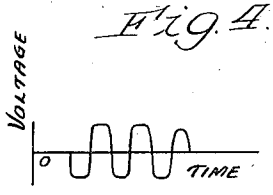


Fig. 4.



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DEFLECTION LIMITER FOR GALVANOMETERS

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Application November 3, 1937, Serial No. 172,629

4 Claims. (Cl. 177—352)

This invention relates to a deflection limiter for a galvanometer, and more particularly to means in the input circuit for such a galvanometer adapted to prevent the development of voltages above a desired maximum across said galvanometer.

One feature of this invention is that it is adapted to protect a galvanometer, particularly of the string type, from the damaging effects of excessive voltages; another feature of this invention is that it permits normal operation of said galvanometer up to the desired maximum voltage input; still another feature is that the initiation and termination of alternating voltage waves of high intensity may be accurately recorded by the galvanometer, while at the same time protection is provided against excessive instantaneous voltages; yet another feature of this invention is that it is particularly adapted for use with an amplifier having automatic volume control incorporated therein, serving to provide protection for the galvanometer initially and to permit said galvanometer to operate without such protection after the automatic volume control portion of the amplifier has achieved control of the output thereof; other features and advantages of this invention will be apparent from the following specification and the drawing, in which:

Figure 1 is a schematic diagram of circuits embodying this invention; Figure 2 is a diagram representing the voltage output of the amplifier illustrated as a box in Figure 1; Figure 3 is a diagram illustrating the voltage output of the tube illustrated in Figure 1; and Figure 4 illustrates the voltage developed across the galvanometer.

The present invention is a continuation-in-part of my application, Serial No. 159,994, filed August 19, 1937, for a signal controlled amplifier.

While galvanometers of various types have been used for a considerable period in various electrical work to give a mechanical record or indication of a voltage, these have been used almost entirely in connection with circuits where the intensity of the voltage input to the galvanometer would not vary widely, and could be foretold with sufficient accuracy to enable protection of the galvanometer. That is, where a voltage only varies in average intensity through a relatively small range the galvanometer can be so arranged as to indicate the highest instantaneous voltage without damage to itself, and yet a good indication will be afforded of the lower intensity voltages.

Where the average intensity of an alternating voltage varies through a range of perhaps twenty thousand to one, as is the case in apparatus used for geophysical service work of the kind described in my above-mentioned application, any attempt to make the galvanometer responsive, within its safe operating range, to the highest intensity voltage alternations, would result in no readable indication of the lower intensity voltages. This is particularly true of the apparatus disclosed in detail in my preceding application and shown diagrammatically here, where the amplifier handling the output of a seismometer has automatic volume control means incorporated therewith, so that the amplification factor of the amplifier may be varied through a wide range.

Since, when there is no signal, an automatic volume control system causes the amplifier to have its greatest sensitivity, or the highest overall gain, the initial input or first few alternations of current from the seismometer are amplified to the fullest gain of the amplifier. That is, depending on the time constant used, it requires a definite fraction of a second for the automatic volume control means to take control of the amplifier and reduce the gain to a point where the output is at the contemplated or desired level.

The present invention is disclosed in connection with apparatus particularly designed for use in geophysical exploration work of the type in which an explosive charge is detonated at a particular point and the vibrations resulting therefrom and transmitted through the adjacent terrain are picked up at various points by seismometers which convert the physical wave into a voltage wave, this voltage wave being subsequently amplified and recorded in some convenient way, as by a string galvanometer and a moving photographic strip. The resulting record comprises oscillations of relatively low frequency, and by analysis of the wave form, time intervals, and other data found on the record made by various seismometers from any one detonation the geology of the sub-surface can be deduced.

The compression waves produced in the terrain by the detonation of the charge, and received by the seismometers and subsequently transformed into similar electrical waves, are of low frequency. The average intensity or mean amplitude of these waves, moreover, will generally decrease in less than five seconds to a value of less than one ten thousandth of the initial value. In order to make a readable strip record, therefore, the over-all gain of the amplifier must be varied considerably during the reception of the signal, and this variation in gain is accom-

plished, at least in part, by automatic volume control circuits of a kind disclosed more fully in my preceding application. The use of such automatic control means, however, since it results in a very great amplification of the initial voltage alternations, which are already of considerable intensity, requires some means for protecting the recording galvanometer.

The present invention accomplishes protection of the galvanometer by having the input circuit thereto so arranged as to provide, in one or more circuits, an effective or input impedance across which the input voltage for the galvanometer is developed, and providing means for reducing the total effective impedance when the instantaneous voltage thereacross would exceed a desired maximum were the impedance left unchanged.

In the particular embodiment of this invention illustrated herewith, a plurality of circuits are illustrated, each being adapted to energize a different string of a multiple-string galvanometer. Since these are identical, only one circuit will be described in detail. Referring now to the first or upper circuit, a seismometer 10, adapted to receive compression waves and produce similar voltage waves is connected to the input of an amplifier 11. This amplifier is one having a high over-all gain, and includes an automatic volume control circuit or means so arranged that at least a part of the total variation in gain possible in said amplifier will be controlled thereby. The specific construction of this amplifier forms no part of the present invention and, since it was fully disclosed in my preceding application, will not be again described here. The output of the amplifier is here shown as developed across an impedance 12, to which impedance is coupled the grid and cathode of the amplifying tube 13, which tube furnishes still further amplification of the voltage, but is not under the control of the automatic volume control means in the amplifier 11. The plate of the tube 13 is supplied with operating voltage, through a conventional network, by the lead 14, and is coupled by a condenser 15 to one end of the primary of the transformer 16. The other end of this primary is connected to the center of a biasing resistor 17, and thus to ground through the lead 18. The secondary of the transformer 16 is connected to one string 19 of a conventional string galvanometer. Such a galvanometer, for example, may comprise a harp having ten strings thereon, these strings being located in a magnetic field so that any flow of current therethrough, as a result of voltage developed thereacross, causes movement. These strings are preferably located in the path of a beam of light subsequently striking a moving photographic strip, so that any movement of the strings is permanently recorded on the strip. The strings of such a galvanometer are very fine and very closely spaced, and excessive voltages cause them to tangle or break.

In order to provide protection for the string 19 of the galvanometer illustrated herewith a shunt circuit is provided for the primary of the transformer 16. This circuit includes a pair of contacts 20 and 21 normally closed by the relay bar 22, a pair of rectifying elements 23 and 24, and the previously mentioned resistor 17. A source of biasing voltage, such as a battery, is connected to the lead 25 to maintain a definite desired biasing potential across the resistor 17. This potential is so chosen that half thereof is the desired maximum voltage applicable to the primary of the transformer 16 to develop in the secondary thereof the desired maximum safe operating voltage for the galvanometer string 19. As illustrated, the rectifying elements 23 and 24 are connected in such a manner that one is capable of passing current when the top of the primary of the transformer 16 is positive, and the other when that end of the primary is negative. Thus a shunt circuit is provided for the primary which comes into operation at a voltage determined by the biasing voltage, and thereafter interposes little or no resistance to the passage of current therethrough. That is, the shunt circuit does not interfere with operation of the string galvanometer until the desired maximum operating voltage is reached, but thereupon it imposes a short on the primary of the transformer 16 so that that voltage is not exceeded. As soon as the voltage being developed across the primary of the transformer 16 drops below the desired maximum, the shunt circuit again becomes inoperative, and the galvanometer string 19 again records the true instantaneous voltage.

It is to be understood that "short circuit," as used herein, contemplates a path for current presenting substantially less impedance to the flow thereof than the normal circuit prior to the creation of such a short, rather than a technically absolute short presenting no impedance whatsoever. That is, the rectifying elements in the shunt circuit have a certain amount of resistance. Moreover, because of the presence of a biasing voltage in the particular embodiment of the invention illustrated herewith, the effective impedance across the input circuit is substantial when considered from a dynamic standpoint. Since the voltage drop across the input circuit when the shunt circuit of this embodiment of the invention is operative is three volts, let us say, this value divided by the current flowing would give an appreciable dynamic impedance.

What is accomplished by the circuit illustrated, and what comprises the invention in its broad aspect, is the automatic variation of the effective or dynamic impedance of the input circuit in such a way that, regardless of the output of the tube 13, the voltage developed across the string 19 will not exceed a desired maximum value.

It is believed that the operation of the device will be readily appreciated from the consideration of Figures 2, 3 and 4. Figure 2, for example, illustrates the voltage wave produced in the output of the amplifier 11, the vertical axis representing instantaneous voltage and the horizontal axis, time. This voltage is supplied to the tube 13, which again amplifies it by a definite amount, so that the output of the tube 13, developed across the primary of the transformer 16, might be represented by the curve of Figure 3. These two curves represent the initial alternations at the beginning of recording, the voltages being much greater at this time than a second or two thereafter. That is, at the "first break" or receipt of the first impulse after the detonation of the charge the output of the amplifier 11, because the automatic volume controlled portion thereof is at its highest gain, is so large that it would damage the string 19 of the galvanometer or recording oscillograph. Assuming a six-volt drop across resistor 17, the shunt or deflection limiting circuit would be inoperative until the voltage drop developed across the primary of the transformer 16 exceeded three volts. That is, the rectifying elements 23 and 24 are so biased that they can pass no current until the bias volt-

age is exceeded. Then these rectifiers, which may be of any common type such as copper oxide, offer little or no resistance to the passage of current therethrough, and what is in effect a dead short is placed across the primary of the transformer 16, the impedance across which causes the input voltage for the string 19 to be developed. The curve recorded on the moving photographic strip, representing the motion of the string 19, would therefore appear as in Figure 4. It will be seen that there is no loss of clear definition near the zero or time axis, but that when the instantaneous voltage of each alternation exceeds that desired, the short circuit created by the rectifying elements prevents any further voltage rise. The first few alternations recorded by the oscillograph, therefore, truly represent the wave or curve of Figure 3 up to the maximum instantaneous voltage desired, at which point they are chopped off. As soon as the instantaneous voltage fails to rise above the desired maximum, as is the case on the last pulse shown on Figures 3 and 4, the recorded curve is a true representation of the instantaneous voltage throughout the complete pulse or alternation. Thus the galvanometer is fully protected from damage at the "first break," yet the parts of these earlier alternations adjacent the zero or time axis are cleanly defined, so that the time of the "first break," for example, can be very closely ascertained.

Dry rectifiers, as of the copper oxide type, will pass no current at all in one direction, but will pass current with considerable freedom in the other direction. Assuming that current will flow through the rectifiers 23 and 24 only in the directions indicated by the small arrows, it will be seen that current will flow through the rectifier 23, for example, only when the upper element thereof is positive in voltage with respect to the lower element; and current will flow through the rectifier 24 only when the lower element is positive with respect to the upper element. If a negative potential of six volts with respect to ground is connected to the lead 25 the biasing resistor 17 will be seen to have a six-volt drop across it. The arrangement of the circuit is such, with the transformer primary connected to the midpoint of the biasing resistor 17, that three volts effective bias are applied to each of the rectifier elements 23 and 24, in such a way that this bias must be overcome by a higher voltage before the rectifiers will pass current. Considering first the rectifier 23, it will be seen that the midpoint of the biasing resistor 17 is connected through the primary of the transformer and through the contacts of the relay to the upper element of this rectifier; while the lefthand end of the biasing resistor is connected to the lower element. Since the center of the biasing resistor 17 is three volts negative with respect to its left end, the rectifier 23 therefore has its upper element biased three volts negative with respect to its lower end. There is no current flow under these conditions, since the rectifier will pass current only when its upper element is positive; and before there can be any current flow the upper end of the primary of the transformer 16 must be more than three volts positive with respect to the lower end. That is, all current flow in the output circuit of the tube 13 will be through the primary of the transformer 16 during one-half of the wave being considered until such time as the instantaneous voltage exceeds three volts, whereupon the upper element of the rectifier will become positive with respect to the lower element and current flow will be diverted through this element. Considering the other rectifier 24, it will be seen that its lower element is three volts negative with respect to its upper element, again connected to the midpoint of the biasing resistor 17. In the other half of the wave, therefore, when the lower end of the primary of the transformer 16 is positive, current will not flow through the rectifier element 24 until the instantaneous voltage rises above the three-volt bias. Under each condition, therefore, it will be seen that the beginning and end of an undesirably high voltage wave will pass entirely through the primary of the transformer 16 and actuate the galvanometer string 19; but as soon as the instantaneous voltage of the wave rises above the bias voltage a path of lesser resistance will be provided through the rectifier elements short-circuiting the primary of the transformer.

In order to insure representations of the complete alternations after their intensity or means amplitude has dropped to within the safe working range of the galvanometer, relay means is provided for cutting the deflection limiter out of circuit. This is here illustrated as the contacts 20 and 21, the contact completing bar 22, and the operating coil 26. The relay is adapted to be energized so as to open the circuit between the contacts 20 and 21 at approximately the time interval after the initial impulse, or first break, required by the automatic volume control means in the amplifier 11 to come into control of the output thereof. That is, if the time constant of the automatic volume control system is about one-tenth of a second, the relay would be so arranged as to have a time delay of about one-tenth of a second or a shade over. This time delay may be incorporated directly in the relay, in accordance with known methods, or incorporated in the amplifier 11 from which the actuating coil 26 is energized through the leads 27 and 28. Where the relay is of the time delay type these leads would be merely condenser coupled to the plate circuit of the final or output tube of the amplifier. The deflection limiter thus fully protects the galvanometer until the automatic volume control system has reached equilibrium and is capable of controlling the output of the amplifier; thereafter the deflection limiter is removed from circuit so that if a particular oscillation should exceed the average by a few percent, its top would not be chopped off by the creation of a short through the rectifier elements. Once the automatic volume control system has achieved control of the output it can be depended upon to keep it within a range which will not damage the galvanometer.

While I have shown and described certain embodiments of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims, in which it is my intention to claim all novelty inherent in my invention as broadly as possible in view of the prior art.

I claim:

1. Apparatus for limiting the deflection of the strings of a multiple-string galvanometer adapted to have its strings energized by a plurality of seismometer circuits delivering alternating voltages of varying intensity, each circuit

for energizing a galvanometer string including: an impedance element across which said voltage is developed; and a shunt circuit for said impedance element, said shunt circuit including means for blocking current flow therethrough until the voltage applied to said shunt circuit rises above a desired maximum, said means thereafter interposing substantially no impedance to current flow through said shunt circuit.

2. Apparatus for limiting the deflection of the strings of a multiple-string galvanometer adapted to have its strings energized by a plurality of seismometer circuits delivering alternating voltages of varying intensity, each circuit for energizing a galvanometer string including: an impedance element across which said voltage is developed; a pair of rectifying elements connected in a shunt circuit around said impedance element, said rectifying elements being so arranged that current may pass in either direction in said shunt circuit; and means for biasing said rectifying elements to prevent operation thereof until the instantaneous voltage across said impedance element rises above a desired maximum.

3. Apparatus of the character described for geophysical surveying, including: a plurality of seismometers for supplying alternating voltages of varying intensity; a plurality of means for amplifying said voltages, each of said amplifying means including automatic volume control means; a multiple-string galvanometer; circuits coupling each of said amplifying means to a different string of said galvanometer to furnish the operating voltage therefor; and means in each of said circuits for limiting the deflection of the galvanometer string which it energizes, said means short circuiting said circuit when the instantaneous voltage therein rises above a desired maximum.

4. Apparatus of the character described for geophysical surveying, including: a seismometer for supplying an alternating voltage of varying intensity; means for amplifying said voltage, said means including automatic volume control means; a string galvanometer; a circuit coupling said amplifying means to said galvanometer to furnish the operating voltage therefor; means for limiting the deflection of said galvanometer, said means short circuiting said circuit when the instantaneous voltage therein rises above a desired maximum; and automatic means for rendering such deflection limiting means inoperative at the termination of a time period substantially equal to the period required for said automatic volume control means to assume control of said amplifying means.

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