

July 27, 1937.

W. H. T. HOLDEN

2,087,949

ELECTRICAL ATTENUATOR

Filed Sept. 23, 1932

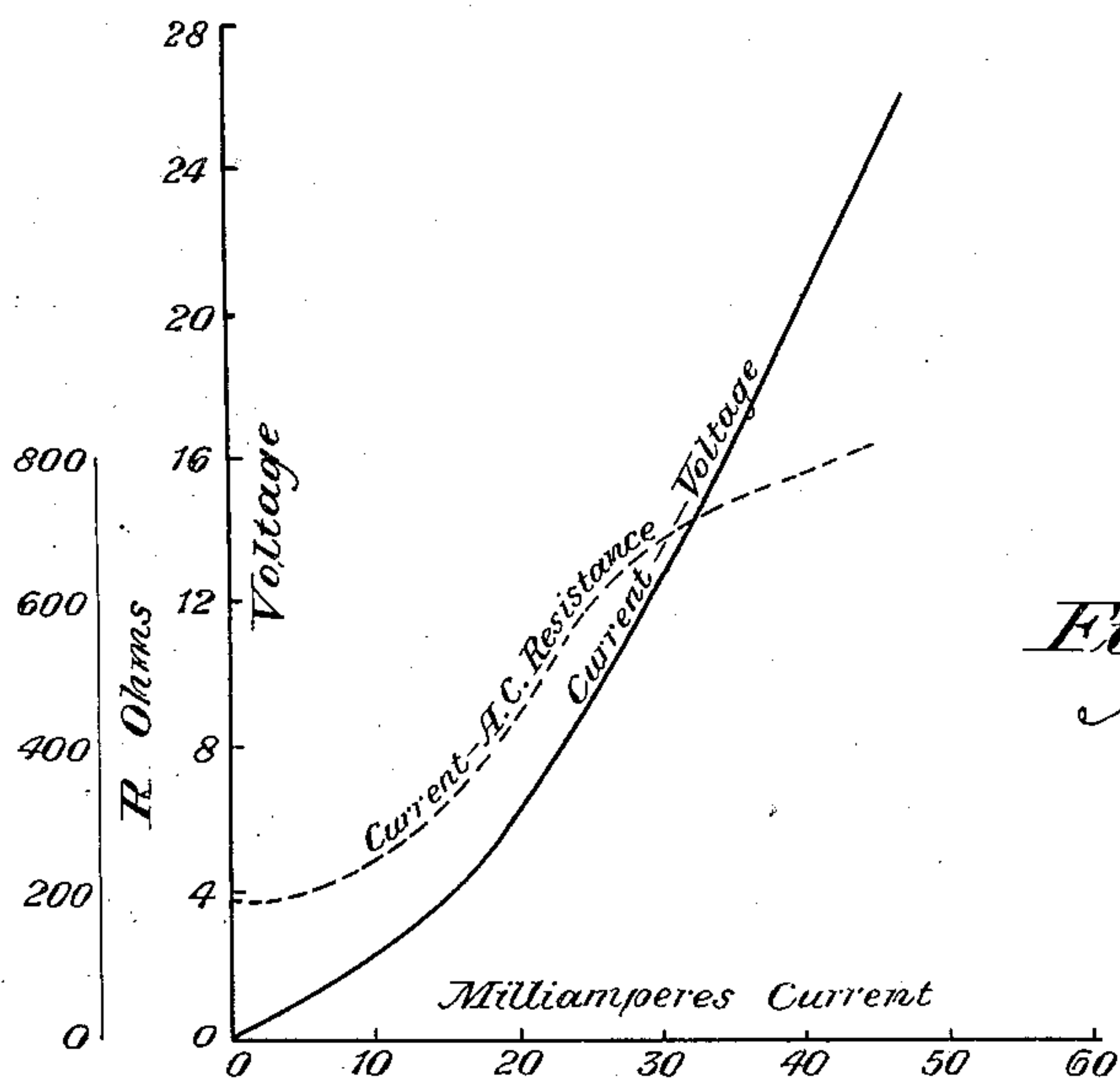


Fig. 1

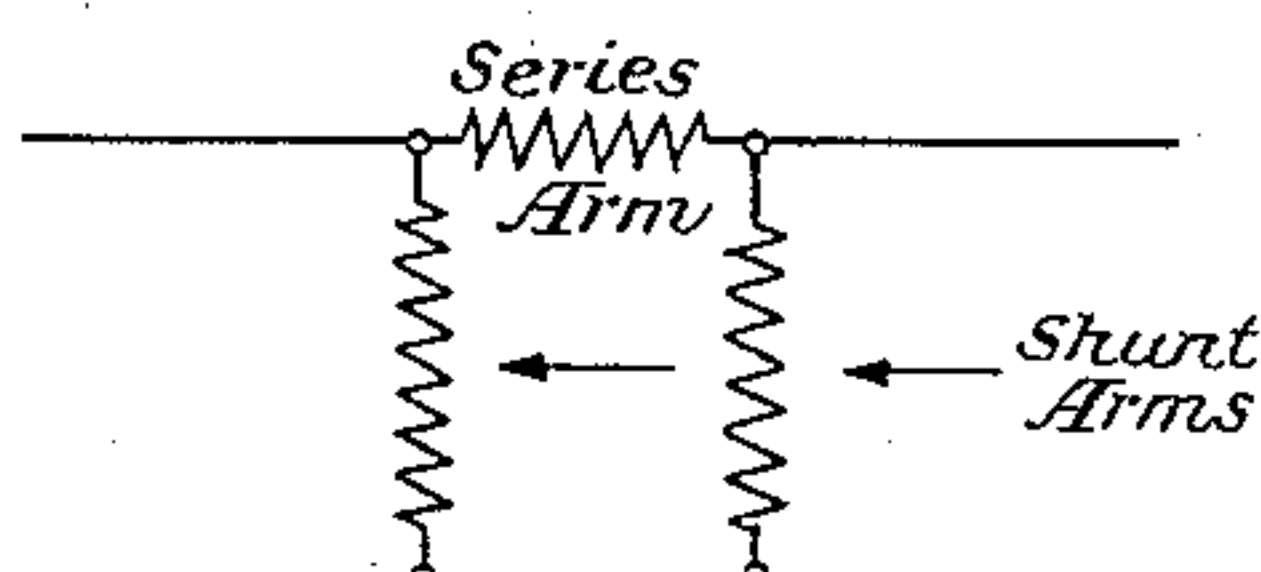


Fig. 2a

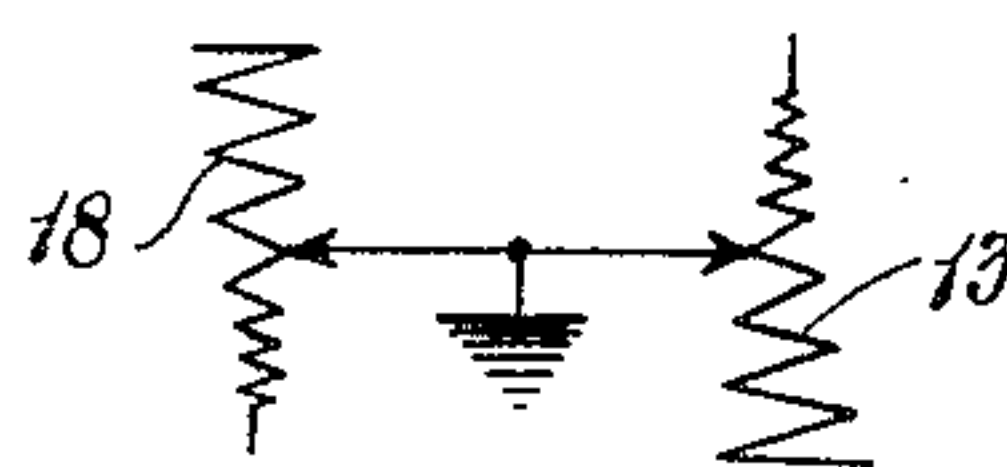


Fig. 3a

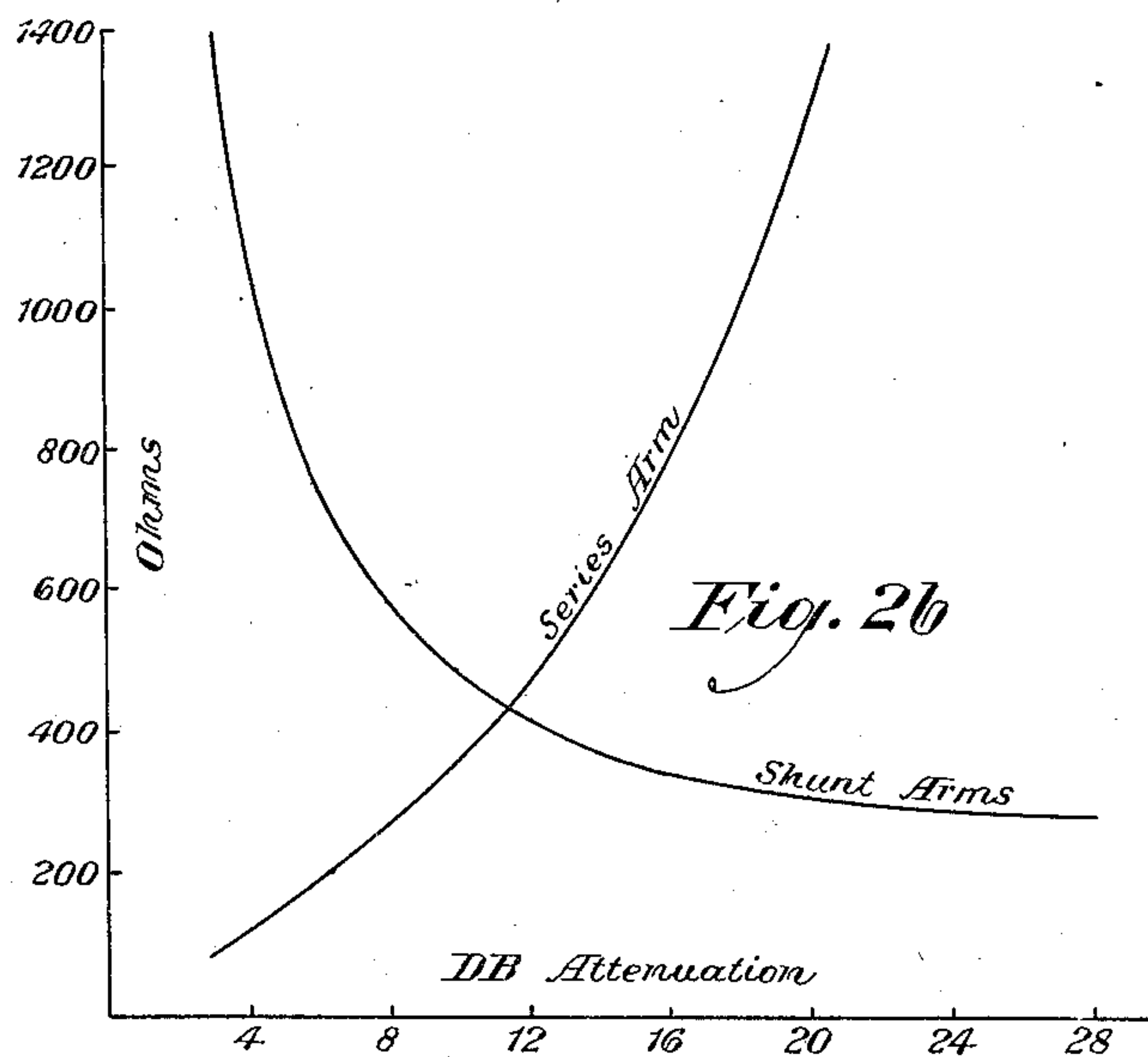


Fig. 2b

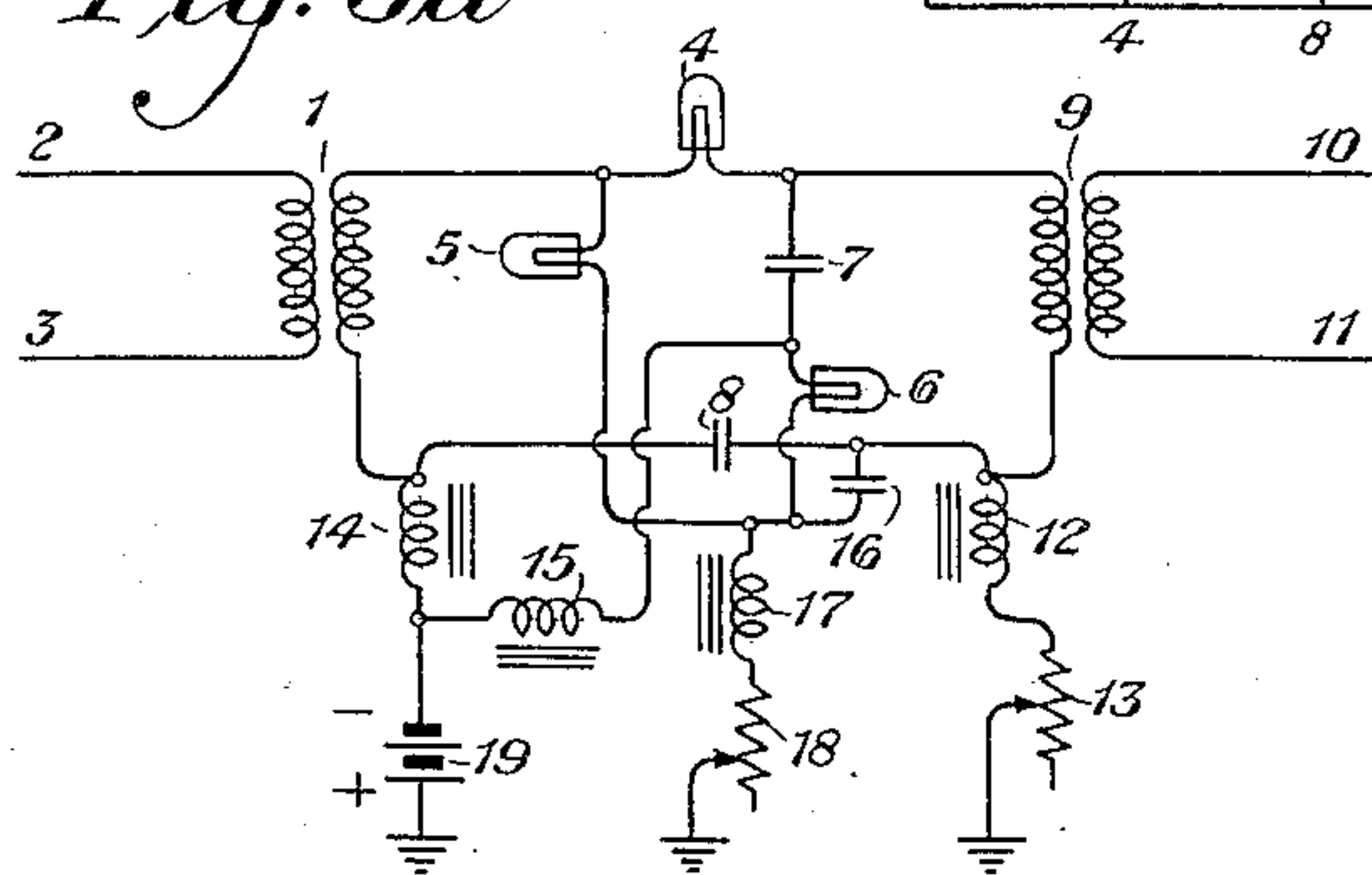


Fig. 3

INVENTOR
W. H. T. Holden
BY
J. E. Holden
ATTORNEY

UNITED STATES PATENT OFFICE

2,087,949

ELECTRICAL ATTENUATOR

William H. T. Holden, Brooklyn, N. Y., assignor
to American Telephone and Telegraph Com-
pany, a corporation of New York

Application September 23, 1932, Serial No. 634,616

11 Claims. (Cl. 178—44)

This invention relates to electrical circuits and more particularly to variable attenuation networks such as may be employed for introducing a variable loss or attenuation into an electrical circuit, particularly in a circuit for the transmission of the electrical currents used in communication of intelligence.

While in the past it has been the practice to provide attenuation networks by the use of wire wound resistances which can be made variable by the provision of sliding contacts that slide directly upon the resistance wire or move across contacts connected to taps and are brought out from the aforesaid resistances, these arrangements have not been entirely satisfactory. The sliding contact bearing upon the resistance winding results in wear, eventually breaking the resistance wire and causing an open circuit. Furthermore, because of the nature of contact materials necessarily employed, it is found that the contact is apt to produce undesired fluctuations in resistance which result in noise. Much effort and many complicated constructions have been utilized in order to reduce this noise difficulty as well as the wearing property, but it has generally been the experience of those skilled in the art that such sliding contact devices are unsatisfactory.

The other alternative of utilizing a tapped resistance, the taps of which are connected to a succession of studs or buttons across which the movable contact arm moves, has been found much more satisfactory, as the contact pressure can be made large, and the contact arm and studs can be made of materials adapted to give good contact, but this construction is costly and, giving only discrete steps instead of continuous variation, results in large and clumsy switches if it is desired to cover a large range in small steps. For this reason it is desirable to provide means for producing a continuous variation of attenuation without requiring the use of movable contacts in the transmission path. It is one of the objects of this invention to provide an arrangement which overcomes the difficulties aforementioned.

In many cases in the telephone art it is desired to provide a considerable number of variable attenuator devices which are operated simultaneously to produce the same variation in attenuation in each of a number of circuits. This has required complicated mechanical arrangements, having long drive shafts interconnecting the various movable contact arms, or complex electrical circuits to secure the same results by simultaneous operation of groups of relays. One of the further objects of this invention is to provide means for the simultaneous control of a plurality of variable attenuators without requiring

mechanical linkages or complex electrical circuits.

Other objects of this invention may be understood from the following description, when read in connection with the accompanying drawing in Figures 1 and 2b of which are certain curves employed to show some of the features of the invention; Fig. 2a one form of network to which the invention may be applied; Fig. 3 one embodiment of the invention, and Fig. 3a a modification of one section of Fig. 3 of the drawing.

Fig. 1 of the drawing shows graphically the characteristics of a tungsten filament in vacuum, as used in certain types of incandescent lamps. The particular lamp used for the derivation of the curve of this figure was a miniature lamp of the type employed in telephone switchboards. It should be noted that the curve "current-A. C. resistance" is not

$$\frac{E}{I}$$

i. e., the ratio of voltage to current, but

$$\frac{dE}{dI}$$

i. e., the ratio of the differential of voltage to the differential of current, and the latter ratio was taken from the curve "current-voltage", graphically. It is this characteristic that is employed in the practice of this invention.

Fig. 2b of the drawing shows two curves exhibiting the relative resistance values of the series and shunt arms of a so-called π type of attenuation network shown in Fig. 2a. By comparing the data disclosed by the two curves of Fig. 2b, it may be seen that if the series and shunt arms of Fig. 2a are made up of lamps of the type for which the curves of Fig. 1 were obtained, then the values of current required in the series and shunt arms to produce attenuations may be shown to be the following values:

Attenuation (decibels)	Lamp currents	
	Series arm (milliamperes)	Shunt arm (milliamperes)
6.....	0	40
8.....	12.5	24
10.....	16.5	21
12.....	20.5	19
14.....	25	17.5
16.....	40	16

It will thus be seen that a useful range of 10 decibels may be obtained. By utilizing two of these devices in cascade, a range of 20 decibels can be obtained, and so on.

In order to introduce and control the current in the lamp filaments independently of the sig-

nalizing currents, which are to be controlled by the attenuator, the arrangements shown in Fig. 3 may be employed. In this figure, reference characters 2, 3 and 10, 11 designate the circuits extending to other apparatus on either side of the variable attenuator element. This element is made up of metallic filament lamps 4, 5 and 6 each of which is preferably in vacuum. Transformers 1 and 9 separate the attenuator circuit from the circuits 2, 3 and 10, 11. This attenuator circuit is unsymmetrical to ground with respect to the pairs 2, 3 and 10, 11 which will ordinarily be connected to equipment which is not electrically unbalanced to ground. These transformers also serve as a part of the means for separating and isolating the direct current used to control the lamp resistance from the alternating current signaling or communication circuit in which the attenuator is to be employed.

The current flow through lamp 4, which is the series arm of the attenuator, may be traced as follows: Starting from the negative or ungrounded terminal of battery 19, through inductance coil 14, the secondary of transformer 1 to lamp 4, then to the primary of transformer 9, then through inductance 12 to rheostat 13 and to ground and then to the grounded terminal of battery 19. It will be seen that rheostat 13 can thus control the current in the series element formed by lamp 4 and therefore it indirectly controls the resistance of this series element.

Similarly, a current path from battery 19 may be traced through the shunt elements formed by lamps 5 and 6. In the case of lamp 5, this path is from the negative or ungrounded terminal of battery 19, thru inductance 14, thru the secondary of transformer 1 to lamp 5, and then thru inductance 17, rheostat 18 to ground and back to the positive terminal of battery 19. The path through lamp 6 is from the ungrounded or negative terminal of battery 19, thru inductance 15 to lamp 6, then thru inductance 17, thru rheostat 18 to ground and back to the positive terminal of battery 19. Thus, it will be seen that rheostat 18 controls the direct current in flowing thru both lamps 5 and 6, and it therefore simultaneously controls the resistance of these lamps.

Condensers 7, 8 and 16 complete the alternating current paths through the attenuator for the currents of signaling frequency which are controlled by the variable attenuator formed of lamps 4, 5 and 6. These condensers should be of such capacity that their reactance will be negligible for currents of frequencies within the band used for communication purposes in the system operating through the variable attenuator. Likewise, inductances 14, 15, 12 and 17 should be of such value that their reactance at frequencies used in the transmission system is very large compared with the characteristic impedance of the attenuator or the resistance values of any of the elements thereof.

The reactance elements of capacity, i. e., 7, 8 and 16, and of inductance, i. e., 12, 14, 15 and 17, are introduced for the purpose of separating the alternating current signaling path through the attenuation network from the direct current supply which heats all of the filaments used as resistance elements of the attenuation network. This is necessary in order that the variations of the resistances of rheostats 13 and 18 shall only affect the resistances in the path of the signaling currents by the change in resistance of the filaments resulting from the change in direct current flowing there-

through. If this were not done, the variations in resistance of these rheostats might tend to counteract the effect of the resulting variations in filament resistance. A further useful result of the use of the aforementioned reactance elements is that any noise resulting from contact resistance variations at rheostats 13 and 18 will be substantially eliminated from the signaling current path.

Rheostats 13 and 18 will ordinarily be operated in opposite directions, one increasing in resistance and the other decreasing in resistance when adjusting the attenuator to a new value of attenuation. The operating mechanism of these rheostats, i. e. their movable arms, may of course be connected to a common control handle in any manner well known in the art, one arrangement illustrating this feature being shown in Fig. 3a. Furthermore, these rheostats should preferably be tapered in their resistance elements, as shown, so that a uniform variation of attenuation will occur as this control handle is moved in a uniform manner.

The arrangement described hereinabove involves a number of tubes having tungsten filaments each of which is surrounded by a vacuum. It will be apparent that tungsten elements are not indispensable to the practice of this invention, for any other elements having large temperature coefficients of resistance and capable of being heated to temperatures of, for example, two or three thousand degrees may be readily substituted therefor, all of which is within the scope of the invention.

The use of metallic filaments for the resistance members of an attenuation network, the resistance of which may be varied by superposition of a heating current differing in frequency from the signaling currents to be attenuated, introduces the requirement that the heating currents should be large in comparison with the signaling currents, so that the latter cannot of themselves produce appreciable fluctuations in temperature and therefore, in resistance, of the network elements. If a sufficiently wide range of values of resistance is to be obtained, it is necessary to raise the temperature of the filament to very large values, as will be obvious when it is considered that the linear term in the relation between temperature and resistance does not exceed 6.3×10^{-3} per degree C., in the case of pure metals and is much less in the case of alloys. Evidently in carrying out this invention metal of suitably high temperature coefficient of resistance should be chosen, and furthermore, a metal capable of withstanding a high temperature is desired so that a reasonably large variation in resistance can be obtained. Tungsten meets these requirements as it has one of the larger values of temperature resistance coefficient, 5.1×10^{-3} per degree C., and will withstand temperatures up to 3000° C., permitting a possible variation of nearly 15 to 1 in resistance. However, tantalum, molybdenum, uranium or other refractory metals might also be used, if desired. Such elements are, however, decidedly superior to any elements of the prior art which have low or negligible temperature coefficients of resistance. In the practice of this invention any change in the resistance of the various series and shunt elements which is, of course, changed by a change in the magnitude of the heating current will produce a corresponding and an appreciable change in the loss of the network.

It may also be desirable in certain forms of this invention to utilize lamps or filaments of different temperature coefficients. Thus, it is possible to employ a filament having a positive temperature coefficient in the series arm and two filaments having negative temperature coefficients in the shunt arms, so that the variation of resistance in opposite directions can be obtained by varying the heating current in the same manner in both arms. Conversely, the series element may have a negative thermal coefficient and the two shunt elements positive thermal coefficients, all within the scope of this invention.

While direct current has been illustrated as the means of heating the filaments of lamps 4, 5 and 6, it would, of course, be possible to utilize alternating current for heating purposes, the alternating current having a frequency outside the range to be controlled by the attenuator.

While this invention has been described with respect to one embodiment thereof, merely for illustrative purposes, it is not to be regarded as limited thereto, but it includes any and all organizations falling within the scope and spirit of the appended claims.

What is claimed is:

1. An attenuator for alternating current circuits comprising a series element having a large temperature resistance coefficient, two elements having large temperature resistance coefficients, one of which is connected across the input circuit of said attenuator and the other across the output circuit as the shunt elements of the attenuator, a source of direct current potential for transmitting current through said elements and thereby heating all of said elements, and means for varying the magnitude of the applied direct current potential so as to control the loss of said attenuator.

2. A variable attenuator for attenuating alternating currents comprising a series element, two shunt elements, one of which is connected across the input terminals of the attenuator and the other across its output terminals, said elements being composed of metallic filaments, means for supplying direct current to all of said elements, means for varying the magnitude of the direct current so as to change the resistance of said elements, and means for separating the direct current from the alternating currents attenuated so that the direct current will change only the resistance of said elements and will not be modulated upon the alternating current output of said attenuator.

3. A π type of attenuation network for a transmission circuit comprising three tubes each having a tungsten filament, the filament of each tube being surrounded by a vacuum, one of the tubes being connected in series with the transmission circuit, another in shunt with the input terminals of the network, and the third in shunt with the output terminals of the network.

4. An attenuation network for a transmission circuit comprising three tungsten filament vacuum tubes, one of which is in series with the transmission circuit and the other two of which are in shunt with the input and output terminals of the network respectively, a source of direct current potential for heating the filaments of said tubes, and two rheostats, one of which is in series with the series tube and said source, and the other in common with the two shunt tubes and said source.

5. An attenuator for a transmission circuit

comprising a first transformer, the primary winding of which is connected to the input terminals of the transmission circuit, a second transformer, the secondary winding of which is connected to the output terminals of the transmission circuit, three tungsten filament vacuum tubes which constitute the elements of the attenuator, one of which is connected in series with the secondary winding of the first transformer and the primary winding of the second transformer, the other two of which are connected across the secondary winding of the first transformer and the primary winding of the second transformer respectively, means for heating the filaments of said tubes, and impedance elements including said series tungsten filament vacuum tube and independent of the means for heating said tubes for facilitating the transfer of alternating currents through the transmission circuit.

6. An attenuator for a signal transmission circuit comprising three elements having nonuniform temperature coefficients of resistance, two rheostats, and a source of direct current potential, one of said rheostats being connected in series with one of said elements which is in series with the signal transmission circuit, the second rheostat being connected in common to the other two elements which are effectively in shunt with the input and output terminals of the signal transmission circuit respectively, and means for supplying energy from the direct current source of potential to all of said elements through the respective rheostats.

7. An attenuator for an alternating current signaling circuit comprising an element in series with said circuit, a pair of elements connected in shunt with said circuit from the opposite ends of the series element, each of said elements being composed of a filament of refractory metal having a large temperature coefficient of resistance, and means independent of the signaling currents to be attenuated for heating said filaments to incandescent temperatures.

8. In combination, a transmission line, an attenuation network in said line, resistance elements in said network each having a non-linear resistance characteristic and varying in resistance according to the current flow therethrough, said elements being connected in series with and in shunt across said line, a source of potential connected to said network for effecting current flow through said elements, and means for varying the impedance of said shunt and series resistance elements inversely upon varying the effective voltage of said source.

9. In combination, a signal transmission circuit having series and shunt resistance elements therein, each of said elements having a non-linear resistance characteristic and varying in resistance according to the current flow there-through, a source of potential connected to said circuit, and means for varying the voltage of said source with respect to said elements to effect maximum impedance of the series elements when the shunt elements have a minimum impedance and vice versa.

10. In combination, an attenuation network having series and shunt impedance elements therein, each of said elements having a non-linear resistance characteristic and varying in resistance according to the current flow there-through, a source of potential connected to said circuit, and means for varying the voltage of said source with respect to said elements to effect

maximum impedance of the series elements when the shunt elements have a minimum impedance and vice versa.

11. In combination, a signal transmission circuit, a network in said circuit, impedance elements in said network each having a non-linear impedance characteristic and varying in impedance according to the current flow there-

through, said elements being connected in series with and in shunt across said circuit, a source of potential connected to said network for effecting current flow through said elements, and means for varying the impedance of said shunt and series elements inversely upon varying the effective voltage of said source. 5

WILLIAM H. T. HOLDEN.