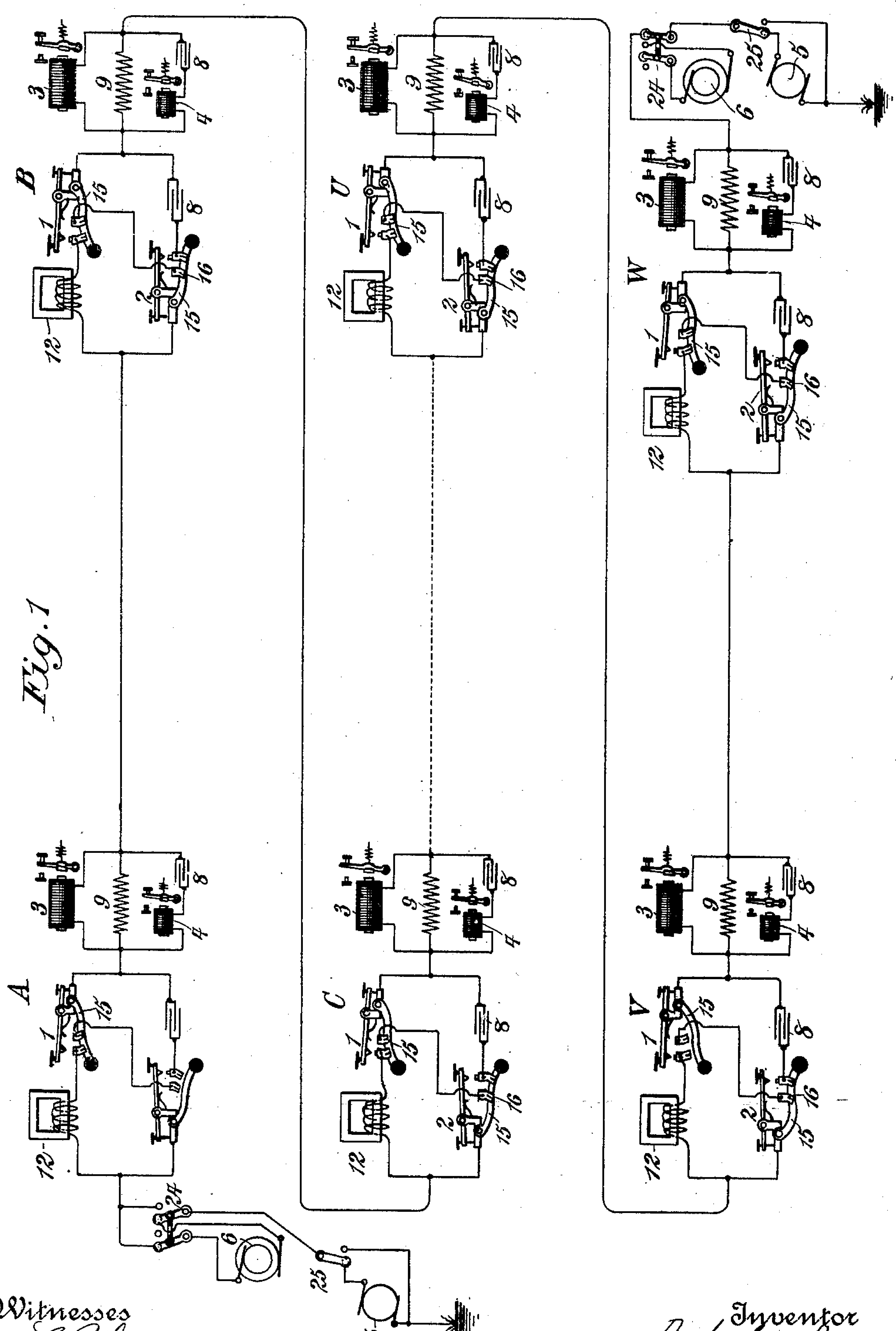
No. 707,830. Patented Aug. 26, 1902.

A. C. CREHORE.

TELEGRAPHY.

(Application filed Oct. 21, 1901.)

(No Model.) 3 Sheets—Sheet 1.



Witnesses
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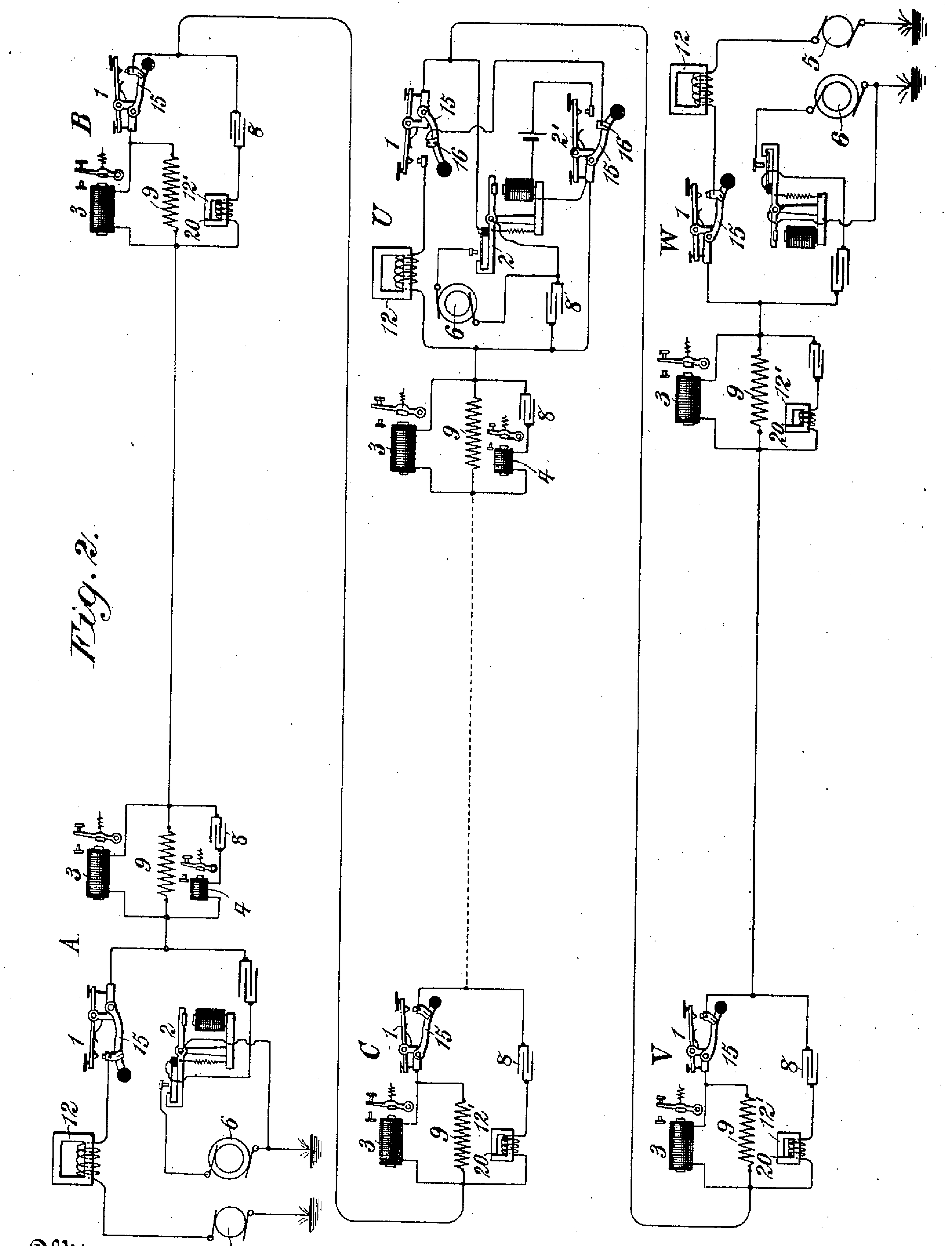

Fig. 2.

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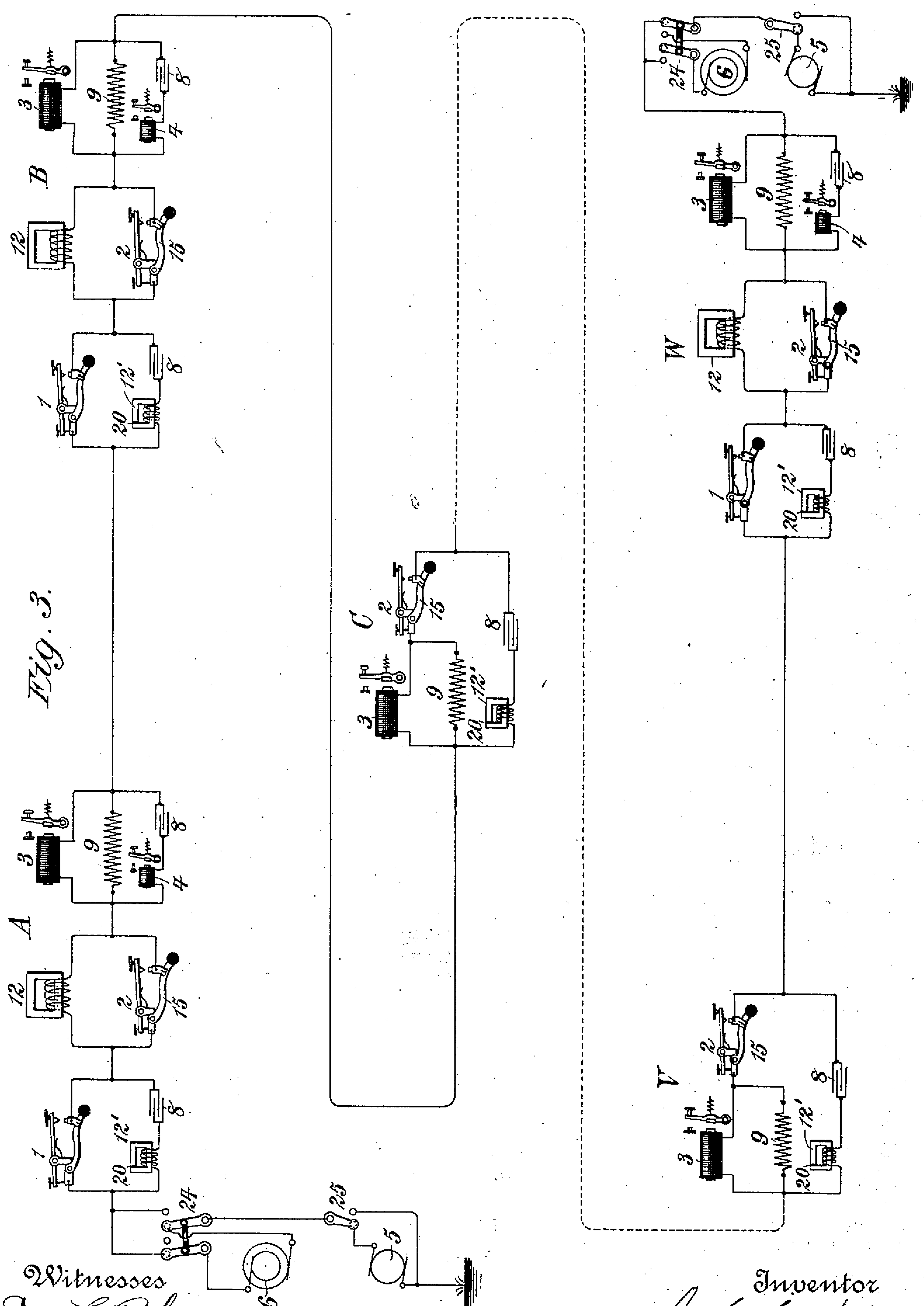

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

ALBERT C. CREHORE, OF TARRYTOWN, NEW YORK.

TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 707,830, dated August 26, 1902.

Application filed October 21, 1901. Serial No. 79,387. (No model.)

To all whom it may concern:

Be it known that I, ALBERT C. CREHORE, a citizen of the United States, and a resident of Tarrytown, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Telegraphy, of which the following is a specification.

My invention relates to that class of telegraphs known as "superposed-current" telegraphs, wherein the capacity of the line is increased by transmitting one class or set of signals over said line by means of momentary currents of short duration and sharply defined or having a high rate of electromotive-force change superposed upon currents having a slower rate of change and, generally speaking, of longer duration, which latter currents will be hereinafter termed for brevity "continuous" currents, while the portion of apparatus through which signals are transmitted by currents of the latter character will be termed hereinafter the "continuous-current side of the system."

As my invention has a large field of utility in connection with circuits wherein the continuous currents are employed in connection with Morse telegraph apparatus, I shall hereinafter describe my invention as carried out in connection with the Morse telegraph-line. It will also be assumed in the following description that the duration of each signal is determined by the length of time during which a succession of pulsatory currents flows, although, as well understood in the art, the transmission of signals on the pulsatory-current side of a superposed-current telegraph may be effected by the use of two pulsations separated by a space of time during which no pulsations flow, a single pulse marking the beginning and another pulse the end of the signal or character.

Telegraphs of this general class have never proved entirely satisfactory in operation, and a great source of difficulty has been the fact that the distributed capacity of the line has the effect of causing the pulsatory currents to decrease rapidly from the transmitting end or point where the source of pulsations is located to the receiving end of the line, and in order to maintain the necessary current at the receiver end for operating the receiver it is necessary to employ currents which become rapidly larger as the product of the resistance and the distributed capacity of the line increases; but if the pulsatory current exceeds a certain value there will be interference with the continuous-current relay on account of the proportion of total current passing therethrough. Moreover, the presence of the necessary condenser-shunts in such systems introduces another disturbing factor, because the larger the current the greater the reaction of the condenser and consequent tendency of the same to disturb the working of the other parts of the system. If there were no distributed capacity to the line, it would be possible by raising the voltage to produce the desired current at the distant end, and the current at the transmitting end would then be the same as at the receiving end, even though there are a large number of intermediate stations; but if there is distributed capacity along the line between each station, as in practice, this causes the transmitting-current to increase and the received current to decrease at a surprising rate, so that the maximum allowable current falls below the required limit.

One of the purposes of my present invention is to increase the limit of pulsatory current which it is permissible to use, thereby increasing the length of line or the number of stations which can be operated.

Another object of my invention is to make it possible to use smaller condensers than have hitherto been employed in systems of this character. In this way the addition of a large number of condensers to the Morse line will have less disturbing influence on the Morse working, while, moreover, the cost of equipment of the line is very considerably reduced. This freedom from disturbance is an especially important factor when the condenser in question is in the shunt around the Morse key, since the practicable limit of condenser capacity which may be used in this location without detection by the operator through its disturbing effect is very small. Again, the ability to use a smaller condenser according to my invention is of value in permitting currents of lower frequency to be used upon the line, and hence the system may be worked with less tendency to inductive disturbances upon neighboring lines.

There are other practical advantages resulting from my invention which will be experienced in working and need not be further dilated upon.

My invention consists, substantially, in employing for the pulsatory-current generator of a superposed-current telegraph one of a character adapted to generate a sine-wave electromotive force and in employing in conjunction with the pulsatory current of sine-wave form and in the various condenser-shunts used in the system a suitable value of inductance or reactance adapted to balance as near as may be the impedance of the condenser, as hereinafter described. Pulsatory systems as heretofore organized have generally employed pulsatory generators depending upon the making and breaking of circuits containing induction-coils and batteries. The pulsations thus produced depart considerably from a sine wave, and hence the use in such systems of a balancing-coil or reactance would be of practically little good, since waves differing from a sine wave do not, either theoretically or practically, permit the impedance of the condenser to be balanced or reduced by the interposition of inductance. In practice the inductance which furnishes the reactance for balancing the reactance of the condenser may be afforded in some cases by coils of electromagnets employed for a receiving part of the system—as, for instance, by the coils for the pulsatory-current receiver—as would be the case where said receiver is in a condenser-shunt around the continuous-current receiver or other portion of the circuit having suitable inductance. In this case it is obvious that the receiver-coils will be preferably wound with the proper number of turns of wire to give them the necessary reactance. In other cases, as when the receiver for the pulsatory-current side of the system is in other relation to the circuit, a supplemental inductance or reactance balancing or counteracting the condenser-reactance would be used in the shunt-circuit with the condenser and whether said shunt be around the continuous-current receiver alone or the continuous-current transmitter alone, or both. The inductance may be furnished by any form of coil; but in general I prefer to employ a special form of inductance-coil. It is difficult in practice to approximate the theoretical balance, because the theory neglects the losses which are necessarily involved when any coil is employed. The loss in the condenser is quite small and may be ordinarily neglected, and it might seem, given the problem of finding a coil to balance three microfarads at one hundred and fifty cycles, easy to find a coil which would reduce the condenser-shunt to a few ohms. To balance three microfarads at one hundred and fifty cycles requires an inductance of about .37 henries; but trials such as I have made have resulted at the best in securing a condenser-shunt measuring not less than one hundred and ten ohms. In practice one hundred and twenty-five ohms will do, which is still a great advantage in the operation of the system over a shunt which with the condenser-line would be, say, three hundred and fifty-four ohms. The coils might be made by winding insulated wire in a coil of sufficient size to produce the required reactance without iron; but this would not be desirable, because the resistance of the coil and the amount of copper required would be too large. If the coil is wound upon an iron core, the size may be greatly reduced for the same reactance, and if the magnetic circuit of the core is completely closed by iron the largest reactance may be produced with a given quantity of iron and copper. The apparent resistance of such a coil for alternating currents is much greater than its ohmic resistance for direct currents and depends largely upon the amount of iron used.

For the purpose of a balancing reactance employed in a system of telegraphy in the manner above described it is desirable that the coils should maintain their values of apparent resistance and reactance as nearly constant as possible for all values of working current. Moreover, while furnishing the required fixed reactance to counterbalance the given condenser at a determined frequency they should also have a comparatively low apparent resistance. These conditions cannot all be satisfactorily attained in the forms of reactance just mentioned—for instance, the closed-magnetic-circuit type of coil does not maintain the apparent resistance and reactance for different values of working currents sufficiently constant in value. An inductance consisting of a coil wound on a straight iron core while it in a measure satisfies the requirement of constant resistance and reactance for all values of working current requires an undue amount of material. I find, however, that the disadvantages of one and the advantages of the other may be secured by using a coil wound upon an iron core whose magnetic circuit is practically closed, excepting for the presence of a small air-gap or interruption in the continuity of the iron core. Such a coil has the advantage that it may be used at all points on the line where current may sometimes be ten and sometimes one hundred milliamperes, whereas if it were of the form in which the reactance would vary with the current it would be obvious that the balance for the condenser-reactance might be good at some points and bad at others.

In the accompanying drawings, Figure 1 shows a system of superposed-current telegraphy in which my invention may be employed and which has arrangements of receiving and transmitting apparatus devised by me and more particularly described and claimed in another application for patent filed by me. Fig. 2 illustrates the application of my invention to a superposed-current telegraph apparatus of modified form. Fig.

3 shows the application of my invention to a system wherein the transmitters for the two sides of the system are arranged in another relation to one another and to the circuit.

Referring to Fig. 1, I have shown a number of stations A, B, C, U, V, and W upon a circuit, each station equipped with pulsatory-current and continuous-current apparatus. In practice a very much larger number of stations might be employed, and at intervals on such circuit, if desired, stations equipped with continuous-current apparatus only might be employed, as indicated in Figs. 2 and 3. In the system illustrated in Fig. 1 the continuous-current and pulsatory-current receivers are arranged in shunt relation to one another, this being one of the arrangements which may be employed when it is desired to equip a line with a large number of way-stations having pulsatory current and continuous-current apparatus, as more particularly described in my pending application filed by me of even date herewith, Serial No. 79,385. 3 is the receiver for the continuous-current side of the system, and in this case is typified by an ordinary Morse receiver adapted to operate after the ordinary manner employed in Morse telegraphs. The receiver for the pulsatory-current side of the system, (indicated at 4,) may be of the ordinary short-core neutral type used in superposed-current systems of telegraphy and adapted to respond to the pulsatory current. The receiver is preferably, however, of the polarized type in order that it may more readily respond to the action of the pulsatory current. The relays control the local circuits of receiving instruments in the ordinary way. In the shunt or branch with the receiver 4 is a condenser 8, employed for the purpose of practically opening the branch in which the receiver 4 is placed to the flow of the continuous currents, and at the same time allowing the passage of the pulsatory currents, which are designed to operate directly or indirectly upon the receiver. The receiver 3 is in the branch having reactance to the pulsatory currents, which reactance may be afforded by the coils of said receiver, and which reactance also operates to force the pulsatory currents into the condenser branch containing the receiver 4. A non-inductive resistance-shunt 9 is also provided, as described in my application Serial No. 79,385, already referred to, to act as a shunt to the relay 3 and afford a short-circuiting or diverting path for the discharge of the condenser 8, thereby avoiding a "kick" in the receiver 4. This non-inductive resistance-shunt aids in permitting the pulsatory currents to flow more freely to stations more distant from the pulsatory-current generator. The continuous-current generators, which might be dynamo-machines, are indicated by the numeral 5. One of these might be used at each end of the line or section of line, said machines being connected, so that their polarities shall conspire. 6 typifies any pulsatory-current generator. For a generator in a system employing my present invention I use one adapted to generate a sine-wave electromotive force and prefer to employ an alternating-current dynamo for the purpose. In the system shown in Fig. 1 a pulsatory-current generator is provided at each end of the line. In practice, however, one of them only will be used at a time, that at station A being shown as in use and as connected to the line through a switching appliance 24, while that at station W is disconnected by switching appliance 24, leaving, however, the two generators 5 at opposite ends of the line connected to the circuit through switching appliances 25. The transmitter for the continuous-current side of the system is shown in this diagram as consisting of the Morse key 2, adapted to open and close a condenser-shunt around a suitable inductance 12, while the key 1 for the continuous-current side of the system opens and closes the circuit through said inductance 12, which latter serves to stop the flow of the pulsatory currents over the circuit during the continuous-current transmission by the key 1. These keys 1 and 2 are here shown in shunt relation to one another. The key 2 operates on the pulsatory-current side of the system by cutting the reactance of 12 into and out of the circuit. Each key has its circuit-closer 15 provided with a supplementary contact 16, and said contacts are connected together, so that when both switches are closed the reactance of the condenser 8 and inductance 12 will be removed from the circuit, and therefore the impedance at way-stations not in use will be so reduced that when the arrangement of receivers shown is employed the system may be worked through a very large number of stations.

In the operation of the system, as shown, the pulsatory currents employed in transmitting from any station circulate over the whole system and through any apparatus in circuit or not shunted. With the arrangement of devices shown said pulsatory currents flow through each branch containing a condenser 8 and receiver 4. In the diagram the switch 15 for the continuous-current side of the system at station V is opened and that for the pulsatory-current side at station A. The receivers 3 and 4 maintain their relations to the circuit at all stations and the pulsatory currents, controlled by transmitter 2 at station A, operate upon the receivers 4 at all stations, the action of the key being simply to open and close the shunt around the inductance 12. Similarly any key at any station may be employed in transmitting signals. In the shunts containing the condenser 8 and receiver 4 the reactance of said condenser is by a suitable construction of the receiver 4 balanced and counteracted by the counter reactance afforded by the coils of said receiver. The inductance of this coil, the capacity of the condenser, and the frequency of the sine-wave current are related to one another, so that the product of the inductance and the capacity by the square of the frequency is equal to one divided by $4\pi^2$, or approximately .025. When this relation of inductance, condenser capacity, and frequency is employed in the condenser-shunt containing the receiver on the pulsatory-current side of the system and the generator is of sine-wave type, many of the difficulties heretofore existing in superposed-current telegraphs will be found to disappear. There may be a practically uniform adjustment of the receiving apparatus for both sides of the system, with little necessity for change of such adjustment, and it will be found that a large number of way-stations may be included in the circuit without requiring an extremely high electromotive force for the pulsatory-current generator employed in the system. Moreover, by the employment of a balancing-inductance the proportion of alternating current which will pass through the continuous-current relay will be very materially reduced, thus making it possible to use a much larger amount of alternating current on the line without disturbing effect upon the continuous-current relay. Theoretically the same result might be accomplished by increasing the size of the condenser; but this is objectionable, because it would be at the expense of the Morse working and add greater cost for equipment.

In the arrangement shown in Fig. 2 the stations A U W are equipped with pulsatory and continuous current apparatus; but the pulsatory-current generators 6 instead of being connected to the circuit and having their pulsations modified by shunting an inductance shunted into and out of circuit are combined with a suitable continuity-preserving transmitter 2, adapted when on its back stop to complete a connection around the pulsatory-current generator 6 and when on the front stop to break the shunt through the pulsatory-current generator into the circuit. Station U is similarly equipped with a transmitter and pulsatory-current generator, said transmitter and generator holding practically the same relation to the circuit and to an inductance and condenser as does the transmitter 2 in the arrangement shown in Fig. 1. In Fig. 2 at the terminal stations the transmitter is in a branch from the condenser to earth and the key 1 is in the connection through an inductance 12 with earth through the generators 5. The inductance 12 serves to prevent pulsations in the generator 6 from being short-circuited to earth. At station U the inductance 12 has the similar function of preventing the current of generator from being short-circuited to earth. Several way-stations B C V are also shown on the circuit, each being equipped with a continuous-current apparatus, comprising the receiver 3 and key 2. The receiver 3 is shunted by the non-inductive resistance 9 and by a condenser 8. The condenser affords a path for the pulsatory currents around the inductance of the receiver 3, and the reactance of the condenser is balanced by the reactance of an inductance 12′, which is of the preferred form already described. The condenser-shunt thus balanced may also extend around the transmitter 1, as indicated. When the circuit-closer 15 for transmitter 1 is closed, it is obvious that there will be present at stations equipped like station B three paths for the current of substantially the same character as that provided by the receivers in Fig. 1, so that each way-station equipped only with continuous-current apparatus may offer no more impedance to the pulsatory currents than those equipped with apparatus for both sides of the system. The case of the condenser-shunt around the Morse key, station B, Fig. 2, differs from that of the shunt around the relay 3 at station A in that the receiver branch is always closed, while the key is sometimes opened. When the Morse key is opened, the only remaining path for the alternating current is through the shunt. Sometimes there is no load or retardation coil required in series with the Morse key and in other cases it is required. If the line has a large number of stations with Morse relays, which are really equivalent to load-coils, and also has small distributed capacity, these coils are not required; but for the present purpose let us consider a two-station line only where these coils are used. It is very objectionable to have the working of the Morse key cause any effect upon the alternating-current relay in the line. It will do this (with a certain adjustment of the relay) if the value of the alternating current flowing is at all disturbed by the opening and closing of the key. For simplification, suppose that there is no line between the terminal stations, but that the circuits have no balancing-coils with the condenser around the keys. If an ammeter is placed in the relay-circuit 4, the alternating-current generator being continuously in the line, the current in 4 will rise when 1 is opened and fall when 1 is closed, the generated electromotive force being constant. This result is surprising when first considered, as it is natural to expect that the closing of the key reduces the total impedance of the line, and thus increases the current in 4. When the proper coils are inserted in the condenser-shunt around the keys 1, it will be observed that when their inductance is larger than the proper value the current in 4 rises upon closing the key 1 and falls upon opening it. This is exactly opposite from the previous effect before the coils were inserted. It is evident, therefore, that there must be some value for the inductance of the coils, which will make it possible to operate the keys 1 without either increasing or decreasing the current in the alternating-current relay. This is approximately the balancing value for the condenser and may be most accurately obtained by adjusting until no effect on the alternating current is observed. It would be necessary to resort to vector diagrams, which obtain when sine-waves are employed, to explain this result.

Fig. 3 illustrates my invention as applied to a circuit wherein the balanced condenser-shunt is employed in connection with the transmitter for the continuous-current side of the system and a condenser-shunt therefor arranged in a relation to the receiver different from that shown in Fig. 2. In Fig. 3 stations A, B, and W are provided with both pulsatory and continuous-current apparatus. Intermediate stations C V are shown provided with apparatus working on the continuous-current side of the system only, although a larger number of stations like C or like B might be employed. The transmitters for the pulsatory and continuous current sides of the system are here shown as arranged in series relation to one another instead of shunt relation. Each transmitter 1 for the continuous-current side of the system is adapted to make and break the shunt around a condenser 8, thereby practically opening and closing the circuit for the continuous currents, while each transmitter 2 for the pulsatory-current side of the system operates to make and break a shunt around the inductance 12 of high reactance and low resistance, thereby throwing said reactance into and out of the circuit, so as to alternately permit the pulsatory currents to flow and to stop their flow. This reactance ordinarily being of low ohmic resistance permits the continuous current to flow readily. It is obvious that with this arrangement of transmitters the pulsatory current must flow through the condenser-shunt 8 around key 1 at stations A, B, and W and similar stations whenever the key 1 is opened during the process of transmitting a message by the continuous-current side of the system, and the pulsatory currents must therefore meet the reactance of the condenser 8. I therefore in accordance with my present invention provide in the shunt with said condenser an inductance 12′ of the character already described and adjust it to balance by its reactance and the reactance of opposite sign produced by the condenser. The resistance of the coil 12′ has the additional function of preventing sparking at the contacts of the key 1.

It is obvious that my invention is applicable to other arrangements of the transmitters and receivers for the two sides of the system.

The generator 6 in the foregoing description is to be considered as typical of any source of pulsating currents of sine-wave type connected to a circuit in the manner shown and described. It might therefore be the secondary of a transformer the primary of which would include a suitable source of pulsating electromotive force, and also, if desired, a key for closing and breaking the primary circuit, in which case the secondary would be connected directly to the branch containing the condenser instead of through the points of the transmitter.

The means for producing on the line a pulsatory current of approximately sine-wave form may obviously be of any kind, and, as understood in the art, it might therefore be a source of direct current combined with means for varying the resistance of the circuit for said source. The term "pulsatory-current generator" is therefore to be understood herein as embracing any means for producing upon the circuit pulsatory current of the form or approximately the form described.

What I claim as my invention is—

1. In a superposed-current telegraph, the combination substantially as described of a pulsatory-current generator adapted to generate an approximate sine-wave electromotive force and condenser shunts or branches around apparatus for the continuous-current side of the system each said shunt having its capacity balanced by inductance, as and for the purpose set forth.

2. In a superposed-current telegraph, the combination with an approximate sine-wave pulsatory-current generator for the pulsatory-current side of the system, a transmitter for the continuous-current side of the system a condenser-shunt around the latter and a balancing-inductance in said shunt, said inductance, condenser capacity and frequency of pulsations being related to one another as described, as and for the purpose set forth.

3. In a superposed-current telegraph, the combination with a pulsatory-current generator adapted to generate electromotive force of the sine-wave type, a continuous-current receiver and transmitter, and a shunt to the same containing a condenser and inductance related to one another and to the frequency of the pulsations in the manner described to reduce the impedance of said shunt, as and for the purpose set forth.

4. In a superposed-current system of telegraphy, a condenser-shunt containing a receiver for the pulsatory-current side of the system in combination with a pulsatory-current generator of the sine-wave type, the frequency of the pulsations, the reactance of the receiver and the capacity of the condenser being related to one another as described to increase the strength of current permissible at the transmitting end of the line.

5. A superposed-current system of telegraphy having a sine-wave generator for the pulsatory-current side and shunts around the continuous-current apparatus at way-stations comprising a condenser and balancing-inductance related to one another as and for the purpose described.

6. In a superposed-current telegraph, the combination with a pulsatory-current generator adapted to generate an electromotive force of sine-wave type, a continuous-current transmitter and receiver and a shunt around said transmitter and receiver containing a

condenser, and an inductance whose reactance is adapted to balance the reactance of said condenser.

7. In a superposed-current telegraph, the combination substantially as described with a continuous-current transmitter and its condenser-shunt, of a balancing-inductance in the condenser-shunt adapted to furnish a reactance that will balance the opposing reactance of the condenser, as and for the purpose described.

8. In a superposed-current telegraph, the combination substantially as described with the continuous-current apparatus, of a condenser-shunt having a balancing-reactance composed of a coil wound on an iron core magnetically closed except for the presence of a narrow gap, as and for the purpose set forth.

9. In a superposed-current system of telegraphy, the combination with a condenser-shunt through which the pulsatory currents flow for operating on the pulsatory-current receiver, of a suitable inductance having a reactance adapted to balance the reactance of said condenser.

Signed at New York city, in the county of New York and State of New York, this 16th day of October, A. D. 1901.

ALBERT C. CREHORE.

Witnesses:

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E. LAWLER.