

April 14, 1931.

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1,800,304

RELAY REGULATING CIRCUITS

Filed July 6, 1928

3 Sheets-Sheet 1

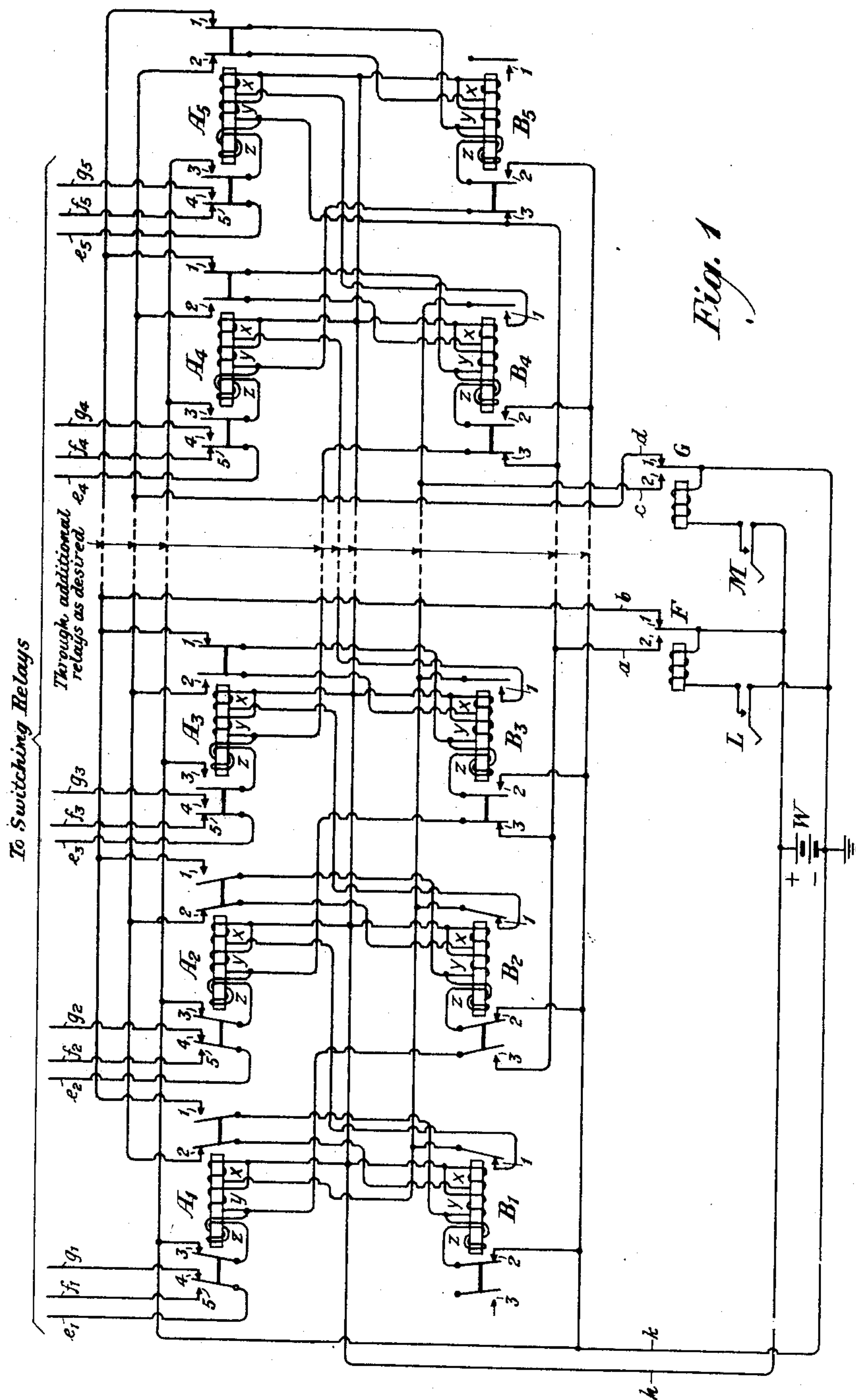


Fig. 1

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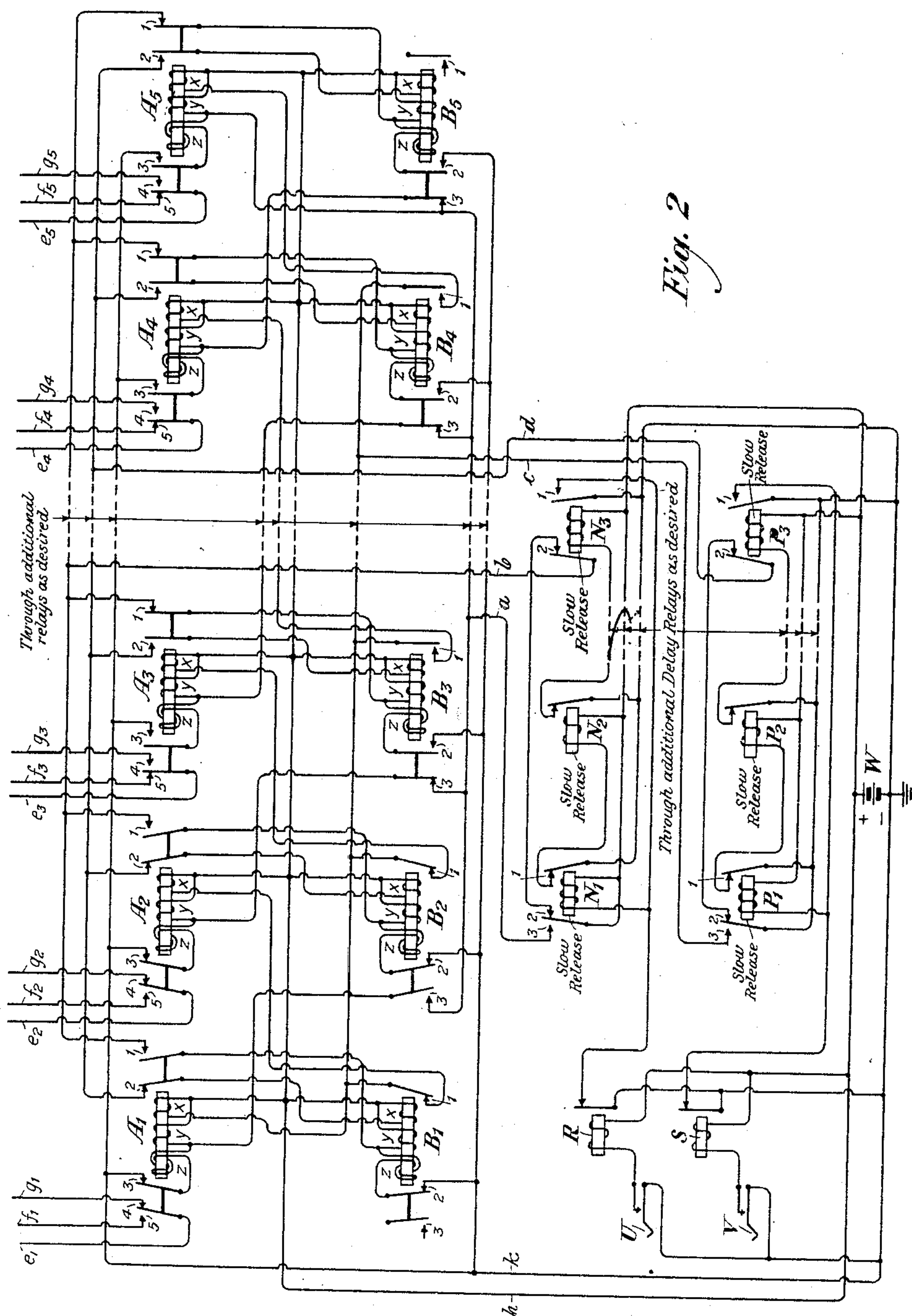


Fig. 2

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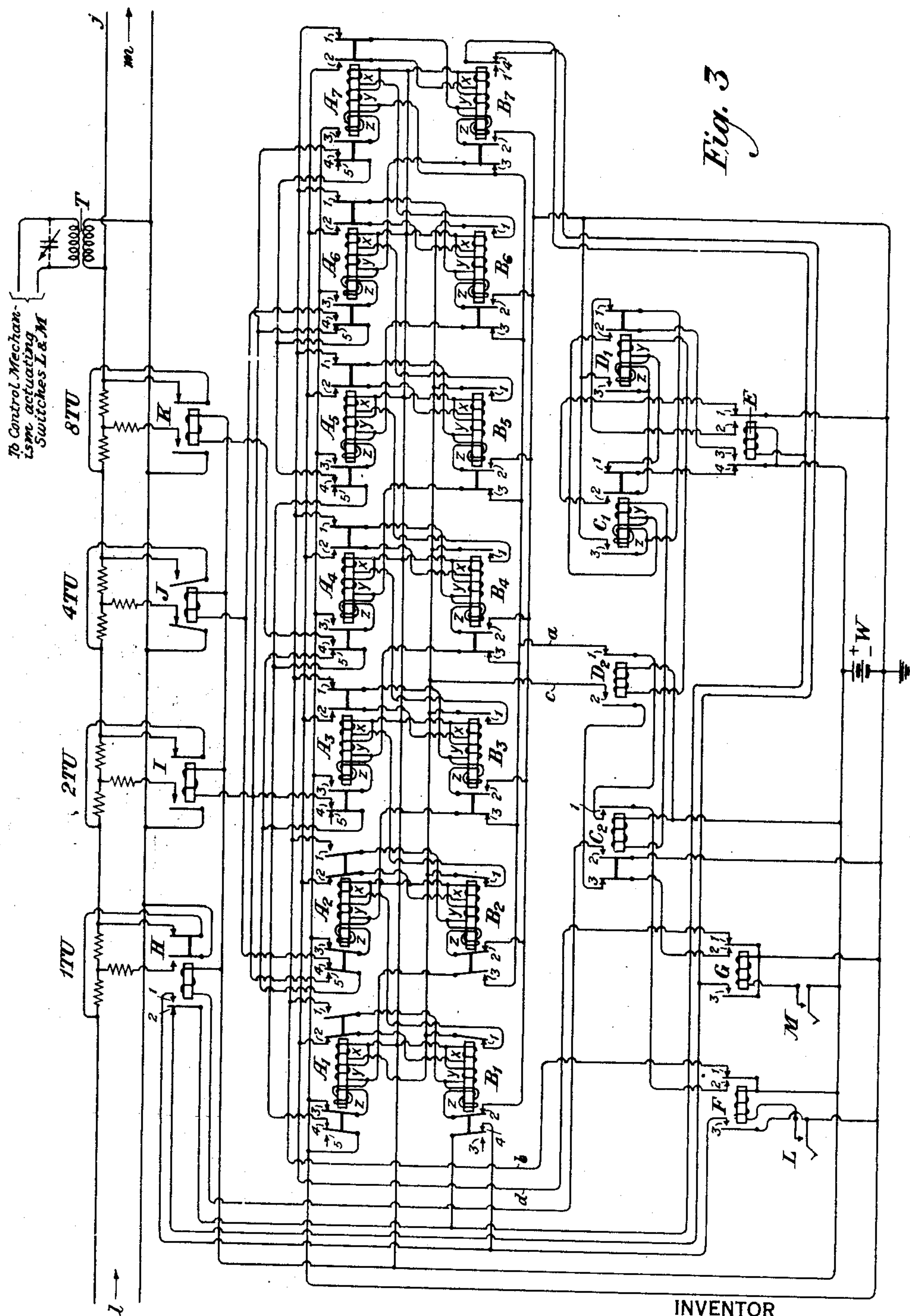
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3 Sheets-Sheet 3



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RELAY-REGULATING CIRCUITS

Application filed July 6, 1928. Serial No. 290,850.

This invention relates to regulating circuits for telephone systems and for signaling systems generally, and particularly to regulating circuits employing trains of relays.

In this invention there will be described regulating circuits consisting principally of trains of relays whose purpose it is to correct for variations in the magnitude of alternating current flowing in a telephone or signaling circuit. In telephone systems or in signaling systems generally which are suitable for the transmission of voice frequency signals, a regulating circuit of the above mentioned type is deemed practically necessary because in such systems there are substantial variations in attenuation in the transmitting media, due particularly to changes in the conditions of the weather. A suitable regulating circuit may preferably be employed to correct for such variations in attenuation in order to maintain the transmission equivalent of the transmitting medium highly constant. A specific application of the various regulating circuits to be described hereinafter may be made in connection with an automatic pilot channel for a carrier system, because at the present time there is a need for equipment which will make automatic corrections in the transmission equivalent of the circuit.

While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its objects and features, will be better understood when read in connection with the accompanying drawing, in which Figure 1 shows a train of pairs of stepping relays the operation of which is first described independently of its relation to a complete regulating circuit of the type shown, for example, in Fig. 3 of the drawing, and in which Fig. 2 shows a similar train of pairs of relays which are actuated by different operating circuits.

Referring to Fig. 1 of the drawing, there is shown a pair of relay trains, there being two relays for each step, one in each train. Relays A_1 and B_1 comprise the first step; relays A_2 and B_2 the second, and so on, the number of relays employed depending upon

the number of steps there are to be in the system. Each of these relays includes three windings, two of which are designated x and y and which are wound inductively, and a third designated z wound non-inductively. Each relay of the upper train, A_1, A_2, A_3 , etc., has four armatures, the first two of which are mechanically coupled by means of a bar of insulation, the first of these closing a contact 1 when the relay is deenergized and the second closing a contact 2 when the relay becomes energized. The second pair of armatures of each relay of the upper train is also mechanically coupled by a similar bar of insulation, these armatures closing contacts 3 and 4 when the relay is energized, the second of these closing a contact 5 when the relay becomes deenergized. Each relay of the lower train, such as B_1, B_2, B_3 , etc., includes three armatures two of which close contacts 1 and 2 when each relay becomes energized, the third closing a contact 3 when the relay becomes deenergized.

Both relay trains are under the control of two main relays F and G , which are under the control of switches or keys L and M , respectively. One step including a relay of the upper train and a corresponding relay of the lower train may be completed by the closing and opening of one of the switches, switch M being responsible for stepping the relay trains up in ascending numerical order by successively operating relays A_1, B_1, A_2, B_2 , etc., and switch L being responsible for stepping the same relay train down in descending numerical order by releasing relays A_5, B_5, A_4, B_4 , etc.

In Fig. 1, the circuit arrangement is shown in the condition in which steps 1 and 2 are operated. In other words, relays A_1, B_1 and A_2, B_2 are operated. Suppose that switch M then is closed. Current will then flow from battery W through the winding of relay G and the contacts of switch M , thereby operating relay G . The armature of relay G will be attracted to open contact 1 and to close contact 2. Current will then flow from battery W through winding x of relay A_3 , the interconnecting circuit including the armature and contact 2 of relay G , arma-

ture and contact 1 of relay B_2 , winding x of relay A_3 and conductor h . Relay A_3 will then operate and become locked by the closure of its contact 3, the locking circuit including battery W , conductor h , windings y and z of relay A_3 , armature and contact 3 of relay A_3 and conductor h .

Suppose that switch M is now opened. Relay G will be released, its armature closing contact 1. Current will then flow from battery W through winding x of relay B_3 , causing relay B_3 to operate, the interconnecting circuit including battery W , conductor h , winding x of relay B_3 , the armature and contact 2 of relay A_3 and the armature and contact 1 of relay G . The closure of contact 2 of relay B_3 will cause that relay to become locked, the locking circuit including battery W , conductor h , windings y and z of relay B_3 , armature and contact 2 of relay B_3 and conductor h .

One step upward is thus completed by the operation of relays A_3 and B_3 upon the closing and opening of switch M , the closing of switch M causing relay A_3 to operate and the opening of that switch causing relay B_3 to operate. Upon closing switch M again, a relay A_4 may be operated, and upon opening this switch, a corresponding relay in the lower train, relay B_4 , is operated, thus completing another step, and so on. It will be seen, therefore, that the relays step up in the order A_3, B_3, A_4, B_4 , and so on, and that it is impossible to operate any relay in either train until the preceding relay in the above order has been operated.

In the circuit arrangement shown in Fig. 1, in which steps 1 and 2 are shown in their operated conditions, suppose that switch L is closed. Relay F then operates, current flowing from battery W through the winding of relay F and the contacts of switch L . The armature of relay F then opens its contact 1 and closes its contact 2. The positive terminal of battery W is then connected through the armature and contact 2 of relay F and through the armature and contact 3 of relay B_3 to the junction of the inductive and non-inductive windings y and z , respectively, of relay A_2 . The other terminal of winding y of relay A_2 is connected to the positive terminal of battery W through conductor h . Accordingly, the inductive winding y of relay A_2 becomes short-circuited, whereupon relay A_2 becomes released. The non-inductive winding z of relay A_2 is then connected to battery W to prevent excessive current from flowing through the armature and contact 3 of relay A_2 during the short interval of time required for relay A_2 to release, the interconnecting circuit including battery W , armature and contact 2 of relay F , armature and contact 3 of relay B_3 , non-inductive winding z of relay A_2 , armature and contact 3 of relay A_2 and conductor h .

Suppose that switch L is now opened. Relay F then releases its armature, closing contact 1. The positive terminal of battery W is then connected to the junction of the inductive and non-inductive windings z and y , respectively, of relay B_2 through the armature and contact 1 of relay F and armature and contact 1 of relay A_2 . The positive terminal of battery W is also connected to the other terminal of inductive winding y of relay B_2 through conductor h . Accordingly, inductive winding y of relay B_2 is short-circuited and relay B_2 releases.

Thus, one step down is completed, releasing relays A_2 and B_2 upon one closing and one opening of switch L , relay A_2 being released when switch L is closed, and relay B_2 being released when switch L is opened. If switch L should be closed again, relay A_1 will release, and when switch L is opened again, relay B_1 will release. It will be seen, therefore, that the relays of the trains shown in Fig. 1 step down in the order A_2, B_2 and A_1, B_1 , and that it is impossible to release any relay in either train until the preceding relay in the established descending order has been released.

It is to be noted particularly that as a step is taken upwardly or downwardly the A relay of each step is the first to be operated or released, respectively. The importance of this note will become apparent in connection with the consideration of the switching relay circuit shown in Fig. 3 of the drawing, in which the switching event is the first in the course of taking a step either up or down.

One armature of each A relay moves between contacts 4 and 5, the fixed terminal of this armature being connected to a conductor e , while contacts 5 and 4 are connected to conductors f and g . These conductors of the various A relays lead to the various switching relays, to be subsequently described.

Fig. 2 shows the same pair of relay trains as is shown in Fig. 1, operated to step these relay trains downwardly through conductors a and b and to step upwardly through conductors c and d . The operating circuit is somewhat different, however, being arranged so that as soon as the switch V is closed the trains will start to step up and will continue to do so, with a certain time interval between steps, until switch V is opened. Similarly, if a switch U is operated, the trains will step down in a similar manner until switch U is opened. This will be more fully described hereinafter.

Relays P_1, P_2 and P_3 and relays N_1, N_2 and N_3 are slow acting or slow release relays of, for example, the dash-pot type, all of these relays being shown in their operated condition. It will be apparent that each of these relays requires a definite time interval for

its complete operation or release, and that the time required for its complete operation or release may be controlled in a manner well known in the art.

Relay P_1 is under the control of relay S and switch V, and relay N_1 is under the control of relay R and switch U. When relay S is unoperated, relay P_1 is operated, due to the flow of current from battery W through the winding of relay P_1 and the armature and contact of relay S. Relay P_2 is also operated due to the flow of current from battery W through the winding of relay P_2 and armature and contact 1 of relay P_1 . Relay P_3 is also operated, current flowing from battery W through the winding of relay P_3 and the armature and contact of relay P_2 . Relays N_1 , N_2 and N_3 are similar to relays P_1 , P_2 and P_3 and are under the control of relay R and switch U, and relays N_1 , N_2 and N_3 are also operated by similar currents from battery W.

When switch V is closed, relay S is operated, due to the flow of current from battery W through switch V and through the winding of relay S. The armature of relay S opens the circuit of its contact, causing relay P_1 to release, one of the armatures of relay P_1 moving from contact 2 to contact 3 after a short period of time. Then, the negative terminal of battery W becomes connected to conductor c through the armature and contact 3 of relay P_1 . Accordingly, relay A_3 becomes operated in the stepping up process in a manner similar to that described in connection with Fig. 1. It will be clear that current will flow from battery W through winding x of relay A_3 and through conductor h. The release of relay P_1 soon results in the release of relay P_2 because the circuit in series with the winding of relay P_2 becomes opened at contact 1 of relay P_1 . Thereafter, relay P_3 will also become released due to the opening of the circuit in series with its winding at the contact of relay P_2 . It will be clearly understood that, while relays P_1 , P_2 and P_3 are slow acting relays and provide a delay in their operation of a substantial time interval, this interval may be increased by adding relays similar to relay P_2 , as indicated in the drawing.

The release of relay P_3 causes the operation of relay P_1 again, current then flowing from battery W through the winding of relay P_1 and through the armature and contact 1 of relay P_3 . The operation of relay P_1 will later cause the operation of relay P_2 , and the operation of relay P_2 will cause the operation of relay P_3 , in the manner already described hereinabove. Thus, one complete cycle of events for relays P_1 , P_2 and P_3 is completed, this cycle including the successive release of these relays and their successive operation thereafter.

When relays P_1 and P_3 become both operated at the same time at the completion of this cycle, the negative terminal of battery W becomes connected to conductor d through the armature and contact 2 of relay P_1 and through the armature and contact 2 of relay P_3 . This will cause the operation of relay B_3 in the manner described in connection with Fig. 1 of the drawing, relay B_3 becoming operated because current flows from battery W through the armature and contact 2 of relay A_3 , through winding x of relay B_3 and through conductor h. Thus, one complete step is completed, this step being started upon the release of relay P_1 and completed upon the operation of relay P_3 .

If switch V still is closed and relay S operated, the operation of relay P_3 , causing the opening of its contact 1, will result in a second release of relay P_1 and the starting and completion of a second cycle, in the same manner as already described hereinabove. Upon the release of relay P_1 relay A_4 will become operated, and when all three relays, P_1 , P_2 and P_3 , are again operated, relay B_4 will become operated. As long as switch V remains closed this stepping action will continue. If at any time in the course of a cycle switch V is opened and relay S is therefore released, the stepping action of the relay trains will be stopped when the particular step in progress at the time, including one relay in the upper train and a corresponding relay in the lower train, is completed. In other words, the cycle of the events with respect to relays P_1 , P_2 and P_3 will become completed in due course by the return of these relays to their normally operated condition. If switch V is opened and relay S released at a time when relay P_1 is operated there will be no interference with the progress of the cycle of events with respect to relays P_1 , P_2 and P_3 , and the cycle will be completed in the normal time interval. If switch V is opened and relay S therefore released at a time when relay P_1 is released, the cycle not having been completed, there will be no interference with the progress of the cycle except that relay P_1 will become operated at a somewhat earlier time, which will result in an earlier completion of the cycle of events.

Relays N_1 , N_2 and N_3 may be the same as relays P_1 , P_2 and P_3 and, as stated hereinabove, are under the control of switch U and relay R. Relays N_1 , N_2 and N_3 control the connection of the positive terminal of battery W between two conductors, a and b, so that the two relay trains may be stepped down in the manner described hereinabove in connection with Fig. 1 of the drawing.

Fig. 3 shows a relay regulating circuit complete except for the apparatus required

for the control mechanism actuating switches L and M. As has already been stated, the chief purpose of this circuit is to correct for variations in alternating current which may flow in a circuit. A portion of the circuit transmitting such current is shown between *l* and *m* in Fig. 3. The input at *l* may vary between certain limits, and it is desired to maintain the output at *m* automatically within smaller limits. This may be done by cutting into or out of the circuit one or more artificial lines, as shown, and these lines may be provided in elements of, for example, 1, 2, 4 and 8 transmission units (TU) of attenuation.

When the input at *l* varies to such an extent as to require adjustment of the artificial line pads in order to keep the output at *m* within certain prescribed limits, the circuit may be made to recognize this condition by means of the control mechanism which may pick off, through a high impedance transformer T, a small part of the output current. This control mechanism will interconnect the secondary winding of transformer T with switches L and M in any well known manner, thus permitting the closing and opening of switches L and M, as desired. One form of such control mechanism is shown in a copending application Serial No. 215,592, filed August 26, 1927. It is the object of the control mechanism to function so as to close and open the switches L and M periodically as the output level at *m* goes beyond the prescribed lower or upper limit, respectively, and to continue such periodic closing and opening until the output at *m* has been brought within a satisfactory limit by the relay regulating circuit and the associated artificial line pads, to be subsequently described.

The variations in alternating current flowing in the circuit may, of course, be due to any cause the effect of which it is desired to counteract. In the case of a transmission circuit suitable for the transmission of telephone messages, the most common causes arise from variations in weather conditions, as stated hereinabove. An alternating current of suitable frequency and of substantially constant amplitude is often transmitted over a line for the purpose of actuating the control mechanism, which will respond to changes in the magnitude of this current caused by changes in weather. Since in the case of a telephone circuit there are transmitted at the same time other currents of widely different and rapidly changing frequencies and magnitudes, it is then necessary for the control mechanism to be sensitive only to the current of the frequency transmitted for regulating purposes. A required sensitivity may be obtained by tuning the input circuit of the control mechanism, i. e.,

in Fig. 3 of the drawing the circuit of the secondary winding of transformer T, to the regulating frequency by means of a variable condenser, or the like.

The stepping relay trains consisting of relays A₁ to A₇ and of relays B₁ to B₇ may be the same as those described in connection with Fig. 1 and may be operated through conductors *c* and *d* for stepping these relay trains up and operated through conductors *a* and *b* for stepping these relay trains down. These relay trains control switching relays I, J and K, which may control artificial line pads exhibiting attenuations corresponding to 2, 4 and 8 transmission units, respectively. The relation between relay H and relays I, J and K will be brought out in the description hereinafter following. Relays I, J and K may be employed to interpose any desired combination of the artificial line pads to provide a change in attenuation of two transmission units per step, as indicated in the accompanying Table I.

Step of relay train	Switching relays operated	Total attenuation
0	O	0
1	I	2
2	J	4
3	I, J	6
4	K	8
5	I, K	10
6	J, K	12
7	I, J, K	14

A fourth artificial line pad exhibiting an attenuation corresponding to one transmission unit is under the control of switching relay H. Relay H is operated by a special relay circuit consisting of relays C₁, C₂, D₁, D₂ and E, in such a way that steps of one transmission unit are provided instead of steps of two transmission units. Table II shows how relay H affects the operation of the system.

Step of relay train	Switching relays operated	Total attenuation
0	O	0
0	H	1
1	I	2
1	H, I	3
2	J	4
2	H, J	5
3	I, J	6
3	H, I, J	7
4	K	8
4	H, K	9
5	I, K	10
5	H, I, K	11
6	J, K	12
6	H, J, K	13
7	I, J, K	14
7	H, I, J, K	15

Upon examination of the combinations shown in Table II, it will be noted that relay H is alternately operated and released as the value of attenuation is to be successively

changed, whether such successive change is an increase or a decrease. It is to be noted also that the relay train does not change step for each successive change of attenuation, and that whether or not it must change its step is determined by the direction in which the change of attenuation need take place.

Relays C₁, C₂, D₁, D₂ and E are shown released. Suppose relay E is arbitrarily operated. Relays C₁ and C₂ will, therefore, operate, current flowing from battery W through the winding of relay C₂, windings *y* and *z* of relay C₁, armature and contact 1 of relay D₁ and armature and contact 2 of relay E. Upon the closure of contact 3 of relay C₁, relays C₁ and C₂ will become locked.

Suppose relay E becomes arbitrarily released. Relays D₁ and D₂ will become operated, current flowing from battery W through the winding of relay D₂, windings *y* and *z* of relay D₁, armature and contact 2 of relay C₁ and armature and contact 1 of relay E. Upon the closure of contact 3 of relay D₁, relays D₁ and D₂ will become locked.

Suppose relay E becomes operated a second time. Then, the positive terminal of battery W becomes connected to the junction of the inductive and non-inductive windings *y* and *z* of relay C₁, through armature and contact 3 of relay E and armature and contact 2 of relay D₁. The positive terminal of battery W is also connected to the winding of relay C₂, which is in series with the inductive winding *y* of relay C₁. Accordingly, winding *y* of relay C₁ and the winding of relay C₂ become short-circuited and relays C₁ and C₂ both release. The non-inductive winding of relay C₁ serves to prevent excessive current from flowing from battery W during the short interval of time required for contact 3 of relay C₁ to become opened.

Lastly, suppose that relay E becomes released a second time. Then, the positive terminal of battery W will be connected to the junction of the inductive and non-inductive windings *y* and *z* of relay D₁ through the armature and contact 4 of relay E and the armature and contact 1 of relay C₁. The positive terminal of battery W is also connected to the winding of relay D₂, which is in series with the inductive winding *y* of relay D₁. Accordingly, winding *y* of relay D₁ and the winding of relay D₂ will become short-circuited and relays D₁ and D₂ will be released, the non-inductive winding *z* of relay D₁ preventing excessive current from flowing from battery W during the short interval of time required for contact 3 of D₁ to become opened.

Table III shows a cycle of events passed by relays C₁, C₂, D₁ and D₂ as relay E is successively operated and released. It will

be apparent that upon a third operation of relay E this cycle of events starts to repeat.

Condition of relays

E	C ₁ , C ₂	D ₁ , D ₂
1st operation.....	Operated.	Released.
1st release.....	Operated.	Operated.
2nd operation.....	Released.	Operated.
2nd release.....	Released.	Released.
3rd operation.....	Operated.	Released.

Relay E is under the control of both relays F and G. When either of these relays operates relay E operates, and when it releases relay E releases, except, however, that relay E remains released and unaffected by relay G when the main transmission channel is shunted by all of the elements of attenuation, and that relay E remains released and unaffected by relay F when the transmission channel is shunted by none of the elements of attenuation. These circuits affected by relay E will be described more fully hereinafter.

The circuit shown in Fig. 3 of the drawing is shown in the condition in which the main transmission circuit or channel is shunted by an element of attenuation representing four transmission units. Suppose the level of the input at *l* of the transmission circuit rises to a sufficient extent so as to require the control mechanism to start in operation. In order to bring the output at *m* back within the prescribed limits, the attenuation of the transmission circuit must be increased. The control mechanism (connecting the secondary of transformer T and switches L and M) will start to close and open switch M periodically. A change in attenuation from one corresponding to four transmission units to one corresponding to five transmission units requires that relay H shall be operated while the relay trains remain on the second step, as will be apparent from Table II. When switch M closes relay G operates, current flowing from battery W through the winding of relay G and switch M. Relay E then operates, current flowing from battery W through the winding of relay E, armature and contact 4 of relay B₇ and armature and contact 3 of relay G. Upon the operation of relay E relays C₁ and C₂ operate, as will be apparent upon inspection of Table III. Relay H will then operate, current flowing from battery W through the winding of relay H and armature and contact 2 of relay C₂. Two resistances will then be connected in series with the transmission circuit, and one in shunt therewith. These resistances, representing an attenuation to the extent of one transmission unit, increase the total attenuation of the transmission circuit to five transmission units, the other four transmission units having been previously provided

by the operation of relay J. The closure of contact 2 of relay G will accomplish nothing at this time because contact 2 of relay D₂ is open. Relay trains including relays A₁ to A₇ and relays B₁ to B₇, remain undisturbed, and there is no change in their step.

When switch M is opened relay G releases, thereby releasing relay E. Consequently, relays D₁ and D₂ operate. The closure of contact 2 of relay D₂ has no effect on the relay trains because contact 3 of relay C₂ is open. Thus, after closing and opening switch M the total attenuation presented to the transmission circuit is changed from four transmission units to five transmission units.

If the output at *m* then becomes normal, the control mechanism will cease to operate. If further attenuation is required to bring about a substantially normal condition at *m*, the control mechanism will operate to close switch M again. Upon inspection of Table II it will be apparent that relay H must be released and relay I operated to bring about a change in attenuation from five transmission units to six transmission units. The closure of switch M operates relay G, which in turn operates relay E. The second operation of relay E causes relays C₁ and C₂ to become released. Upon the opening of contact 2 of relay C₂ relay H will be released. The release of relay C₂ also causes the connection of the negative terminal of battery W to conductor *c* through the armature and contact 2 of relay G, armature and contact 3 of relay C₂ and armature and contact 2 of relay D₂. Relay A₃ of the upper train will then operate, starting a step upward. Relay I will then operate, current flowing from battery W through the winding of relay I, armature and contact 4 of relay A₃, armature and contact 5 of relay A₄ and armature and contact 4 of relay A₁. Accordingly, the attenuation will be increased by one transmission unit. Upon the opening of switch M relay E will be released, and the release of relay E will cause relays D₁ and D₂ to release. The release of relay G will cause the connection of the negative terminal of battery W to conductor *d* through armature and contact 1 of relay G. Relay B₃, in the lower train, will then operate. If an attenuation corresponding to six transmission units is sufficient to bring about a substantially normal output at *m*, the control mechanism will stop operating and switch M will remain open.

Steps downward in the relay trains to bring about a lower attenuation of the transmission circuit, whenever necessary, are accomplished in a similar manner, switch L, not switch M, being then operated by the control mechanism. It should be noted that, upon the closure of switch L relay F becomes operated by the flow of current

through its winding from battery W and through switch L, and that relay E becomes operated, current flowing from battery W through the winding of relay E, armature and contact 4 of relay B₁ and armature and contact 3 of relay F. In other respects the circuits completed in stepping the attenuation downward will be apparent from the description given hereinabove.

Consideration will now be given to the conditions of the circuit when the maximum or the minimum of attenuation is provided by the regulating system. If the attenuation has been stepped up to its maximum, i. e., 15 transmission units, all of the switching relays, i. e., relays H, I, J and K, become operated. If the attenuation presented to the transmission circuit is insufficient to properly reduce the output level at *m*, the control mechanism will continue to periodically close and open switch M, resulting in a periodic operation of relay E. Relay H will then be alternately released and operated, continually changing the attenuation from 14 transmission units to 15, and back again to 14. Such a condition is undesirable, and means have been provided to eliminate that condition. Accordingly, means are provided to prevent the operation of relay E by switch M when both relays B₇ and H are operated. Two parallel circuits, one including contact 4 of relay B₇ and the other including contact 2 of relay H, are inserted between contact 3 of relay G and the winding of relay E, both of these circuits being open when relays B₇ and H have both operated.

In connection with the presentation of the minimum of attenuation for the transmission circuit, it is necessary to prevent any periodic change between zero and one transmission unit by the operation of relay H. In a similar manner, relay E is prevented from being operated by switch L when both relays B₇ and H are released. Two circuits are then connected in parallel relationship between contact 3 of relay F and the winding of relay E, one of these circuits including contact 4 of relay B₁ and the other contact 1 of relay H, both of these contacts being open when relays B₁ and H have both released.

The relay arrangement including relays N₁, N₂ and N₃ and relays P₁, P₂ and P₃, of Fig. 2, may be employed to operate the pair of relay trains and the relay H of Fig. 3. It will be apparent that this may be accomplished by replacing switches L and M and relays F and G by the two groups of relays above mentioned, and by the associated switches U and V and relays R and S, also of Fig. 2. Relays N₁ and P₁ would each then require an additional break contact to perform the functions of contact 3 on relays F and G. It will be understood

that the arrangement of Fig. 3 is thus made suitable not only for the type of control mechanism which, when actuated, periodically closes and opens a switch or key such as L or M, but also for the type of control mechanism which, when actuated, closes and holds closed a switch or key such as U or V in Fig. 2. Furthermore, over-correction of the attenuation caused by possible slow response of a control mechanism such as the latter, may be overcome by the addition of as many slow-acting relays as necessary in the relay groups N_1 , N_2 and N_3 , and P_1 , P_2 and P_3 .

The arrangement shown in Fig. 3 of the drawing permits a great reduction in the number of relays ordinarily required to change the attenuation of the transmission circuit by steps. Here two relay trains, each including seven relays, permit fifteen changes in attenuation instead of seven, as may be ordinarily expected. In other words, seven steps of a pair of relay trains including fourteen relays, are employed to cover a range of fifteen changes in attenuation, or one more than twice as many steps as are provided by the relay trains.

It will be understood that the arrangement of Fig. 3 includes no marginal, slow-acting or slow-release relays and that it, therefore, possesses a high degree of reliability.

It will be understood that the requirements for the control mechanism are moderate in that there are substantially no restrictions upon the manner of operation of switches L and M except that these switches be opened and closed for intervals long enough to operate or release the relays concerned to bring about the proper stepping sequence, and that both of these switches must not be closed simultaneously.

It will be understood that, while this invention has been shown in certain particular arrangements merely for the purpose of illustration, the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a gain control system, in combination, a plurality of relays comprising a first train, a plurality of relays comprising a second train, each relay in the second train corresponding to a particular relay in the first train, two pairs of control relays, means extending from said control relays to the various relays of said first and second trains, whereby a relay in the first train and a corresponding relay in the second train may be operated to change the gain of the system in one direction, and means extending from said control relays to the various relays of said first and sec-

ond trains, whereby a relay in the first train and a corresponding relay in the second train may be released so as to change the gain of the system in the opposite direction.

2. The combination of a plurality of relays comprising a first train, a plurality of relays comprising a second train, two pairs of control relays, means interconnecting said control relays with the relays comprising first and second trains, whereby the relays of said trains may be progressively operated in one order, each relay of the first train operating before the corresponding relay of the second train, and means interconnecting said control relays and the relays comprising said first and second trains whereby the relays of said trains may be progressively released in the opposite order, each relay of the first train always being released before the corresponding relay of the second train.

3. The combination of a plurality of relays comprising a first train, a plurality of relays comprising a second train, and a third group of slow release relays which are normally operated and which, when said third group of relays begin to release, cause the operation of a selected relay in the first train and which, when said third group of relays have been released and operated again, cause the operation of a corresponding relay in the second train.

4. The combination of a plurality of relays comprising a first train, a plurality of relays comprising a second train, a third group of slow release relays which are successively released and then operated to operate a selected relay of the first train and a corresponding relay of the second train, and a fourth group of slow release relays which are successively released and operated to cause the release of a selected relay in the first train and a corresponding relay in the second train.

5. The combination of a plurality of relays comprising a first train, a plurality of relays comprising a second train, a third group of slow release relays which are normally operated, a fourth group of slow release relays, which are normally operated, means for progressively releasing the relays of the third group to cause one of the relays of the first train to operate and step up, means for progressively operating the relays of the third group to cause the corresponding relay in the second train to operate and similarly step up, means to progressively release the fourth group of relays so as to cause a relay in the first train to release and step down, and means to progressively operate the fourth group of relays so as to cause a corresponding relay in the second train to release and step down.

6. The combination of a plurality of re-

lays comprising a first train, a plurality of relays comprising a second train, each of the relays of the second train corresponding to one of the relays of the first train, a first pair of control relays, a second pair of control relays, means whereby the first and second pairs of control relays may be successively released and operated to operate one of the relays in the first train and then to operate the corresponding relay of the second train, and means whereby the first and second pairs of control relays may be successively operated and released to release a relay of the first train and then to release the corresponding relay of the second train.

7. In a gain control system, the combination of a plurality of relays comprising a first train, a plurality of relays comprising a second train, each of the relays of the second train corresponding to one of the relays of the first train, a transmission circuit, a plurality of elements of attenuation associated with said transmission circuit, a first pair of control relays, a second pair of control relays, means whereby the first and second pairs of control relays may be successively operated and released to increase the number of elements of attenuation connected to the transmission circuit, and means whereby the first and second pairs of control relays may be successively operated and released to decrease the number of elements of attenuation connected to the transmission circuit.

8. In a system for the control of gain in transmission, the combination of a plurality of relays comprising a first group, a plurality of relays comprising a second group, each relay of one of said groups corresponding to one of the relays of the other of said groups, a transmission circuit, a plurality of pads of attenuation having magnitudes arranged in geometric progression which may be connected to said transmission circuit, a plurality of control relays which operate in succession, means interconnecting said control relays and the various relays of said first and second groups to operate selected relays of said first group and the corresponding relays of the second group, means interconnecting said control relays and the various relays of said first and second groups to release selected relays of the first group and the corresponding relays of the second group, and means controlled by the relays of both groups to change the attenuation interposed by said pads in said transmission circuit by increments which are in arithmetic progression.

In testimony whereof, I have signed my name to this specification this 5th day of July, 1928.

RUSSELL H. LINDSAY.