

March 26, 1929.

W. M. BAILEY

1,706,837

ELECTRICAL TRANSFORMER

Filed Dec. 5, 1922

6 Sheets-Sheet 1

Fig. 1.

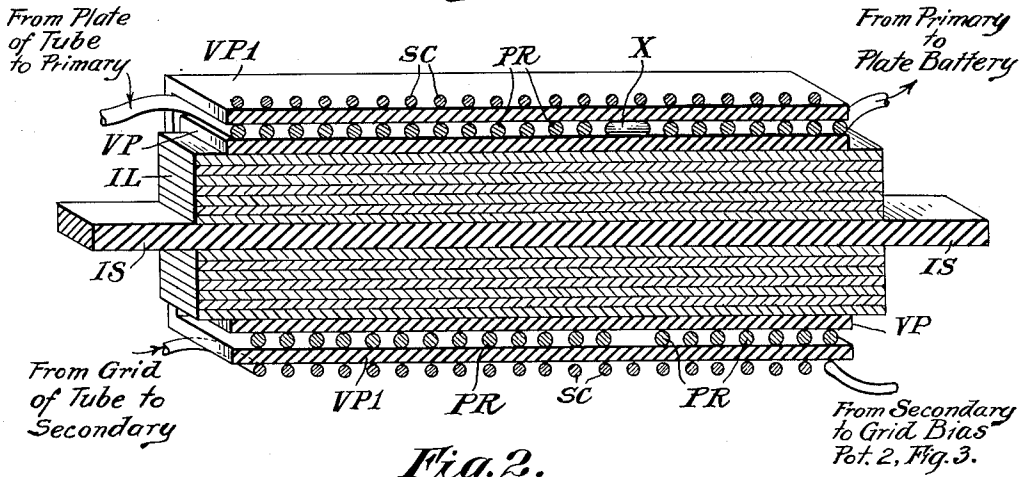


Fig. 2.

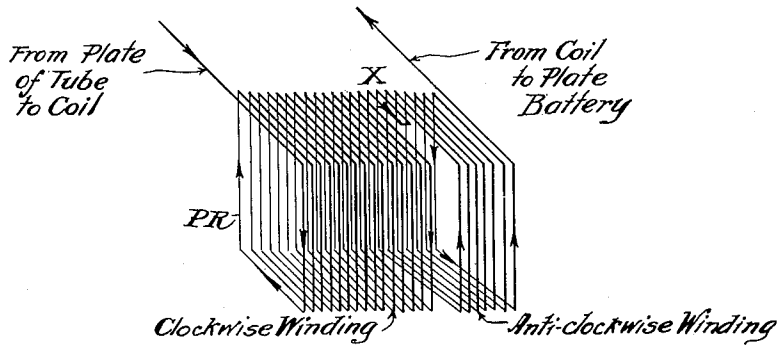
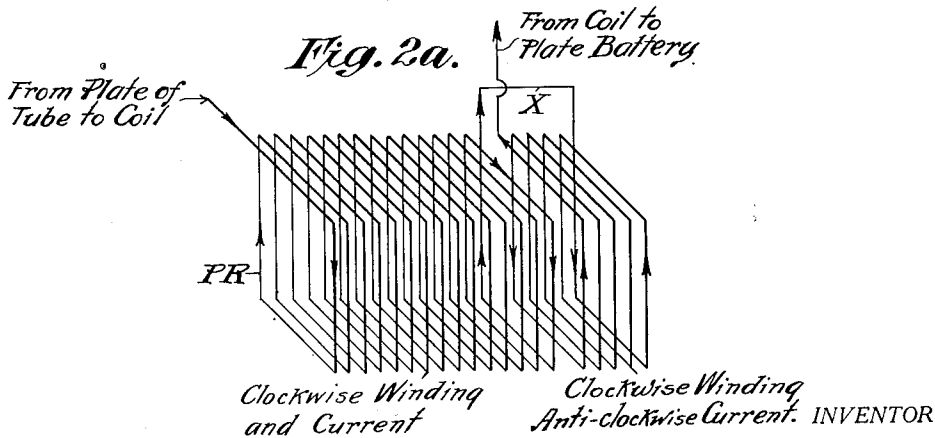


Fig. 2a.



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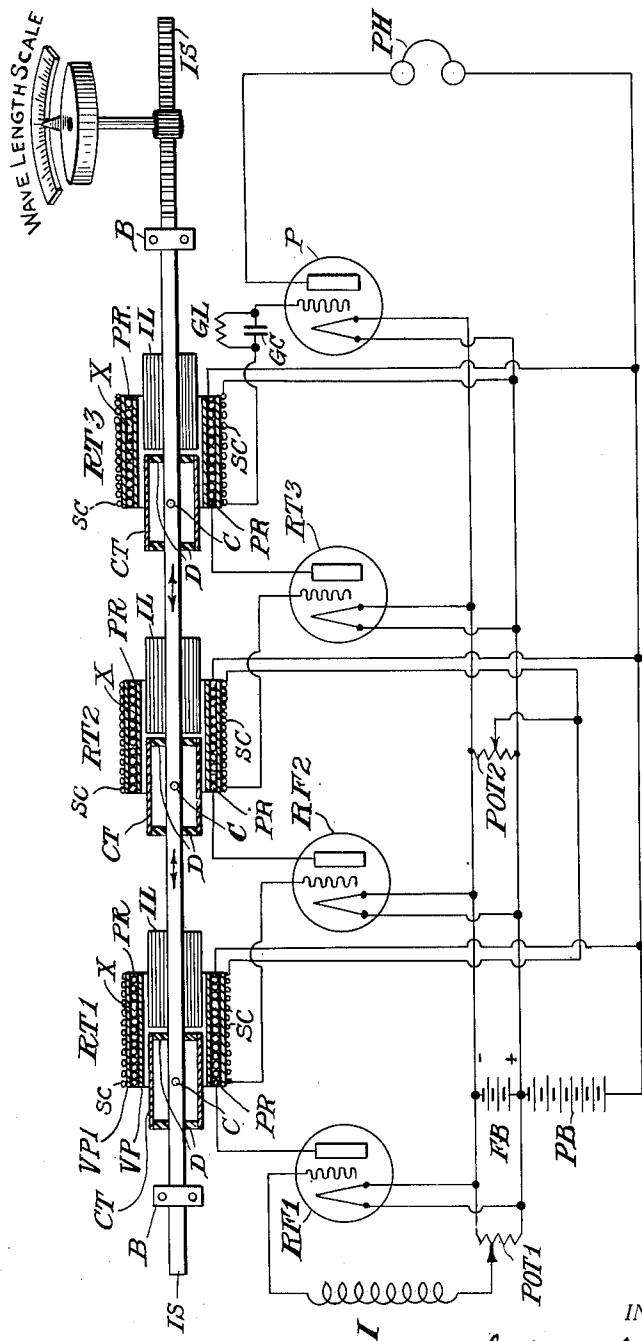
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Fig. 3.



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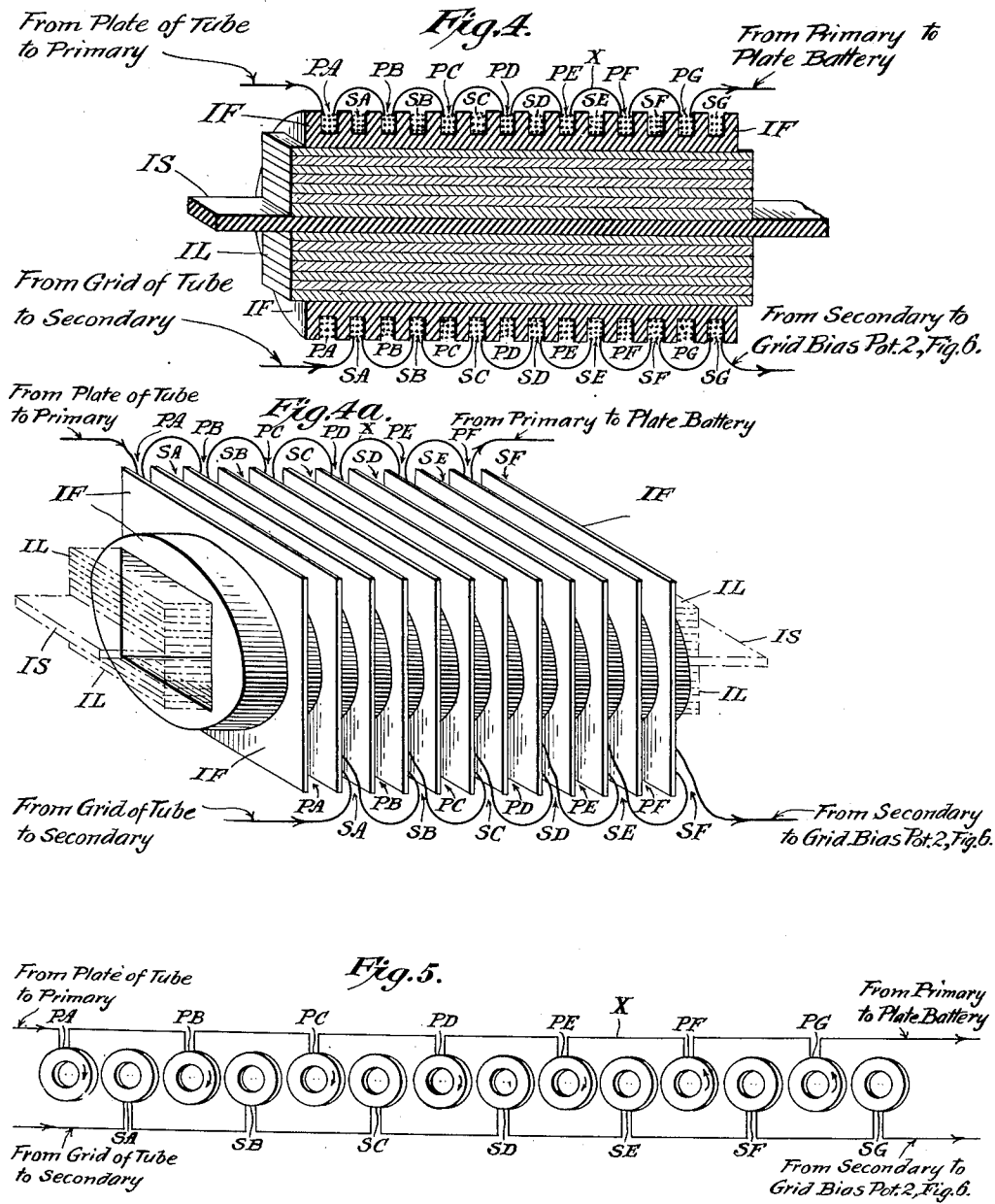
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6 Sheets-Sheet 3



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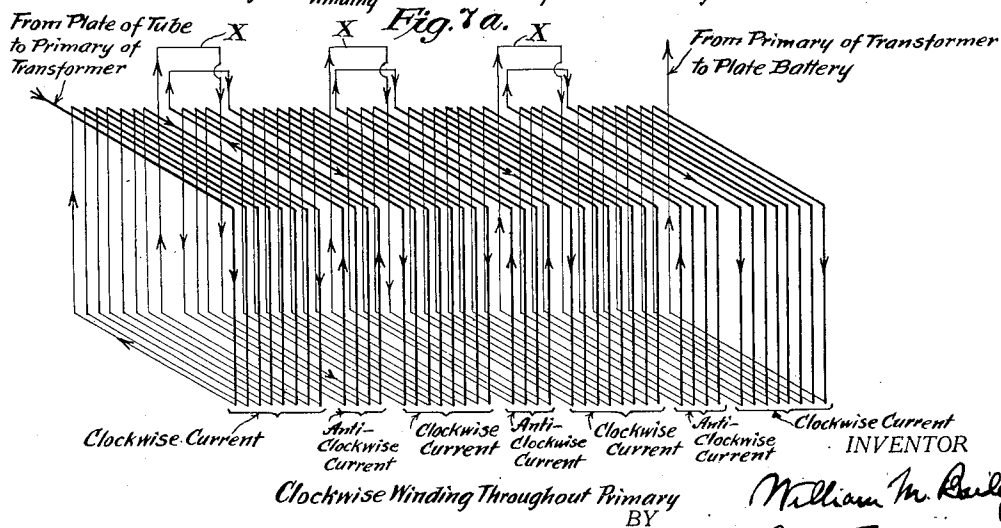
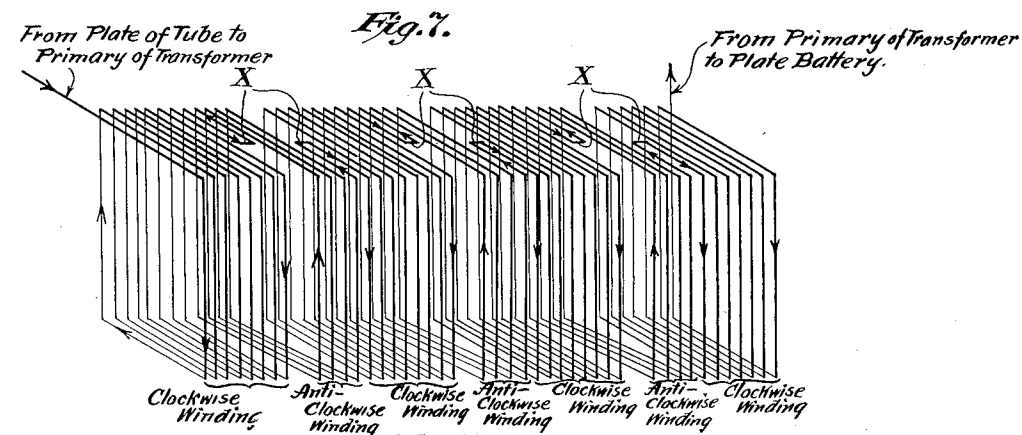
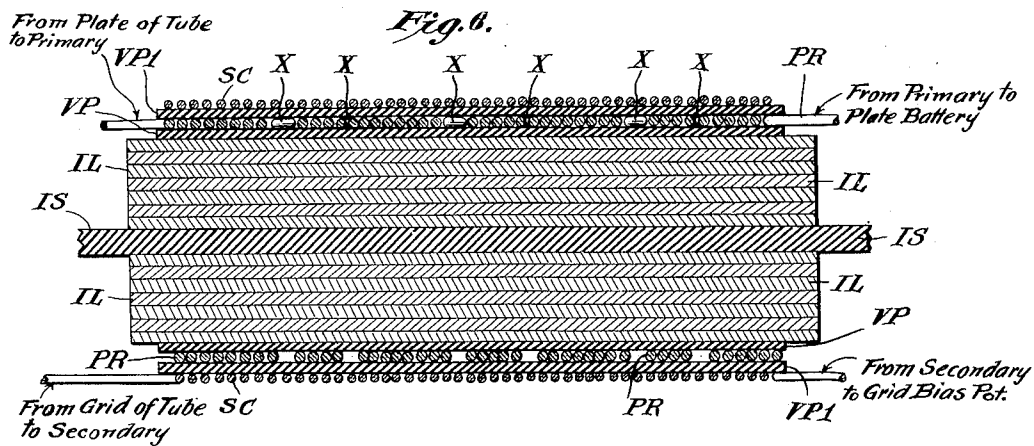
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Fig. 8.

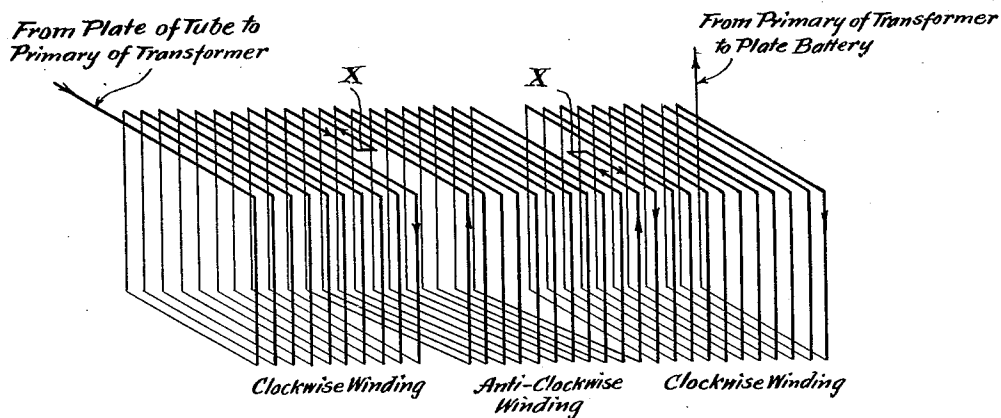
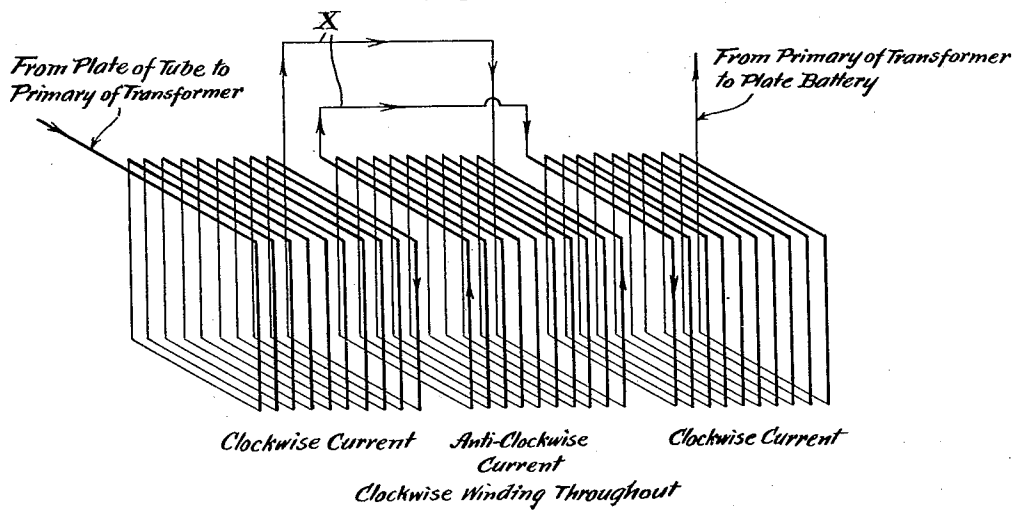


Fig. 8a.



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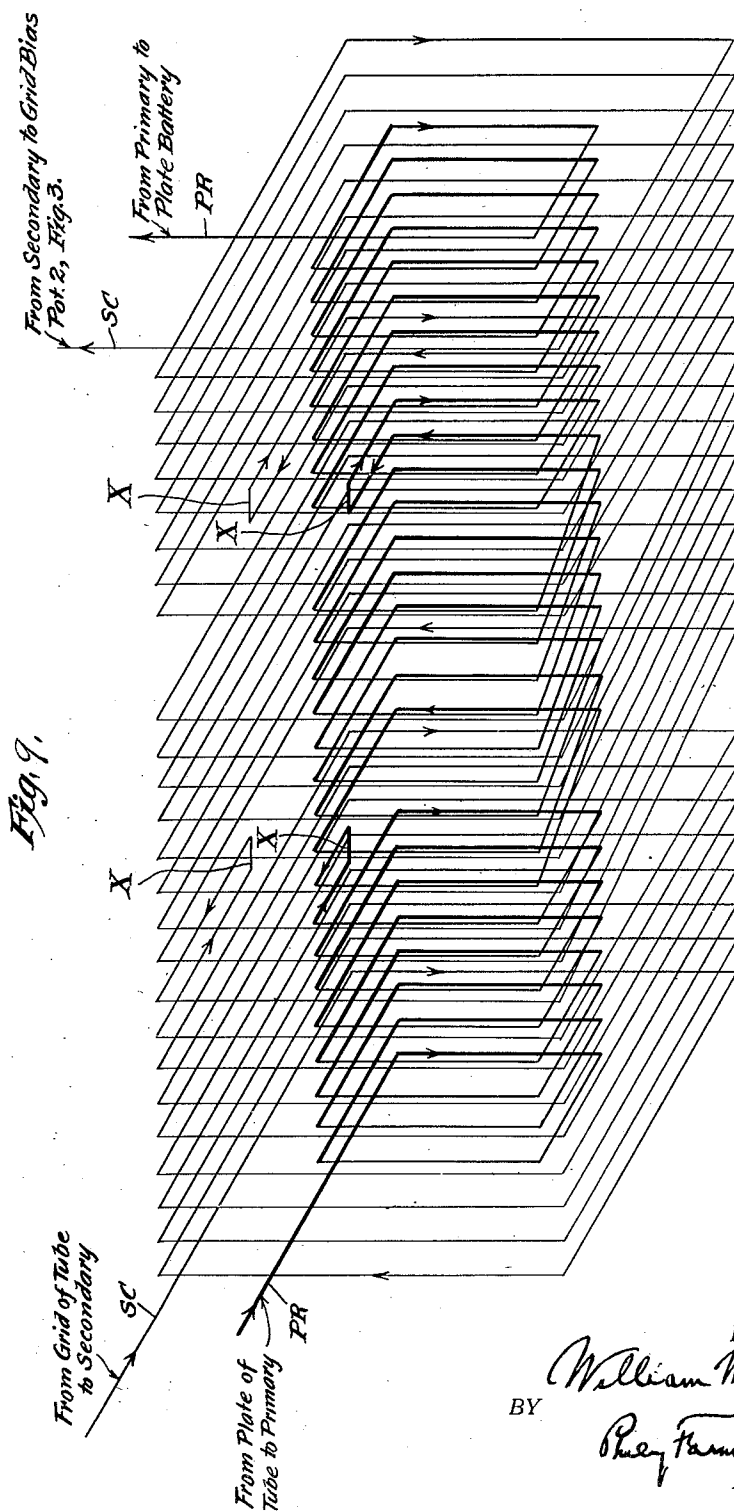
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ELECTRICAL TRANSFORMER

Filed Dec. 5, 1922

6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE.

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ELECTRICAL TRANSFORMER.

Application filed December 5, 1922. Serial No. 604,990.

This invention relates to improvements in electrical transformers, particularly for feeble currents such as those employed in the art of communication by high frequency current, in connection with amplifiers employing currents at high or low frequencies, or both.

The object of the invention is to improve the construction and electrical operation of such transformers.

The invention relates to the various novel features and their combination, as herein disclosed and claimed; and the invention has most particular relation to the construction of transformers employed to couple the successive thermionic tubes of the amplifier receiving set.

Of the drawings,

Figure 1 is a vertical section in perspective of one of my transformers;

Fig. 2 is a diagram of the winding thereon which more clearly shows the arrangement thereof;

Fig. 2^a is a diagram showing a method alternative to that of Figs. 1 and 2 for obtaining the electrical action of the invention in a transformer of the general type of Fig. 1;

Fig. 3 is a diagram of the circuits of an amplifier employing transformers of the form of Figs. 1, 2 and 2^a, with an additional showing of an arrangement for simultaneously moving the cores of all the successive transformers together with compensating damping means;

Fig. 4 is a vertical section in perspective of another form of transformer involving the invention;

Fig. 4^a is a perspective view showing a modified form of support for the type of transformer windings of Fig. 4;

Fig. 5 is a diagram of the coils which are wound on the support of Fig. 4^a for the transformer of Fig. 4;

Fig. 6 is a vertical section of another form of my transformer alternative with that of Fig. 1 or Fig. 4;

Fig. 7 is a diagrammatic illustration of the primary winding of the transformer of Fig. 6 showing more clearly the arrangement thereof;

Fig. 7^a is a diagram showing a method alternative to that of Fig. 7 for obtaining the

electrical action of the invention in a transformer of the general type of Fig. 6;

Fig. 8 is a diagrammatic illustration of the primary winding of another form of my transformer alternative to those of Figs. 1, 4 and 6;

Fig. 8^a is a diagrammatic illustration of a primary winding of another method of obtaining the same electrical action of the transformer of Fig. 8 as is obtained in that of Fig. 8;

Fig. 9 is a diagrammatic illustration of one of my transformers wherein the improvements are applied to both primary and secondary, each winding resembling that of Fig. 8.

Fig. 1 shows a transformer suitable for use in any transformer-coupled tube set such, for example, as that shown in Fig. 3. It is most particularly adapted for use as radio frequency transformer (as in Fig. 3 at RT¹, RT² and RT³). In Fig. 1 the transformer includes a core of iron laminæ IL, the individual laminæ being covered with an insulating varnish to insulate them from one another. These laminæ are supported by a sheet of any suitable insulating material IS (see also Fig. 4), about half the total of laminæ being mounted on the respective sides of the sheet. The laminæ IL are held to sheet IS by an enclosure of varnished paper VP. Over VP is wound the primary coil PR in a manner to be described. Over primary PR is placed a second layer of varnished paper VP¹. Over VP¹ is wound the secondary coil SC of the transformer. The resulting transformer is placed in the circuit of (for example) Fig. 3 in the manner shown; that is, one end of primary PR (an end to be designated later) is connected to the plate of the preceding tube as RF¹ (radio frequency tube 1), the other end of primary PR is to be connected to the plate battery PB (Fig. 3); one end of secondary SC is to be connected to the grid of a succeeding tube (as RF², Fig. 3); and the other end of secondary SC is to be connected to the grid bias potentiometer, i. e., POT², Fig. 3.

Primary PR of the transformer of Fig. 1 is wound in the manner shown in Fig. 2. The portion of PR which is connected to the tube plate is wound say clockwise, and this portion constitutes a larger part of the

entire primary, being shown at the left in Figs. 1 and 2. The remaining portion of primary PR is wound anticlockwise as shown, this portion being located at the right and starting from a point of reversal X. That is, from left to point X, the primary is wound clockwise; at X the direction of winding is reversed, and from point X to the right the winding is anticlockwise.

In Fig. 2^a is shown a method alternative to that of Figs. 1 and 2, of obtaining the same electrical action. In Fig. 2^a the entire primary PR is wound clockwise, but at a point X a reversal is effected between two parts of the winding, by means of reversing the connections of the right-hand smaller portion of the winding. That is, in Fig. 2^a the winding is interrupted at the end of the right-hand larger portion and at the left-hand end of the smaller portion, the two portions being connected by the lead X extending from the right-hand end of the left-hand portion to the right-hand end of the right-hand portion,—the lead to the plate battery being taken from the left-hand end of the right-hand portion. The method in Fig. 2^a is that obtained by means of connections to primary PR itself, whereas the method of Figs. 1 and 2 is effected by means of a reversal in the winding of primary PR itself. The effect of either method is that the magnetic flux due to current in one portion of the winding is opposed to the magnetic flux due to the same current in another portion of the winding. All this is involved in the problem of providing the damping necessary in amplifiers of this type for the purpose of preventing undesirable oscillations in the amplifier circuits. By thus opposing the magnetic fluxes in different parts of the transformer winding, it is possible by the above means to obtain adequate damping by resistance of the wire of the winding without the necessity of using such fine wire as to be mechanically unsatisfactory. The opposition of magnetic fluxes permits increase to such extent of the length of the winding without producing an undue net amount of inductance in the circuits, as to provide the necessary damping by way of resistance of the increased length of wire in lieu of the resistance heretofore provided by a wire of such small diameter as to be liable to breakage on account of weak structure of the wire. The direct effect of the opposition of parts of the winding and resultant opposition of magnetic fluxes is of course to decrease the effective inductance of the coil, which would be unduly increased if attempt were made to remedy the mechanical defects of fine wire by simply using a greater length of wire of larger diameter. Nicrome wire of a diameter of three mils, and well insulated, is suitable, and, notwithstanding its very large diameter relative to that heretofore

used for this purpose, provides the necessary damping resistance on account of the greater length permitted by the feature of reducing the inductance for such greater length by the reversal of magnetic fluxes.

In a multi-stage tube amplifier such as is shown in Fig. 3, the damping conditions are improved also by the following construction. The insulating sheet IS of the transformer of Fig. 1 is extended from end to end of the set as shown in Fig. 3, and the cores IL of each of the transformers are mounted on this extended supporting sheet IS, which then is common to all the transformers of Fig. 3. This construction is made variable for wave length adjustment by movement to left or right, effected by rack and pinion arrangement on a wave length indicator shown at the right in Fig. 3, so that the cores IL may be moved axially in and out of their respective transformers. When the core is directly within its coils, in the case of each transformer, the transformer windings have maximum inductance because of the increased permeability of the space inside the winding for the magnetic flux of the winding, such increased permeability being due to the presence of the iron core inside the winding. When the core is moved away from its position wholly within its windings, the inductance of the winding is reduced. When the core is inside the winding, therefore, the transformer is adapted for the higher wave lengths, and as the core is moved out of its windings, the transformer is adapted for the lower wave lengths due to the reduced inductance of the windings. In connection with these movable cores, there are provided a corresponding number of copper tubes CT, which are secured to insulating supporting sheet IS, as, for example, by pins C and insulating disks D (Fig. 3). These copper tubes are mounted adjacent cores IL, so that they directly follow the movements of the cores and compensate therefore in the following manner. As the core leaves its position inside its coils, copper tube CT begins to enter inside the coils in place of the core, and acts as a short-circuiting turn, thereby decreasing the inductance of the transformer winding below what it would be if air alone were left to take the place of iron core IL. Thus the entrance of copper tube CT acts to decrease the inductance of the winding and adapt it for the lower wave lengths. This action of the copper tube as a short-circuiting winding is due to its closed or tubular nature analogous to a single turn of a short-circuiting winding. The thickness of the tube depends upon the frequency of the currents employed, being only a few mils thick at radio frequencies. Tubes CT also have the effect of increasing the damping of the transformer winding, thereby compensating for the loss

of desirable damping by the withdrawal of iron cores IL. These variably positioned cores IL with their compensating copper tubes T permit shifting of the wave length range of the entire amplifier. In practice, they have been used to shift the wave length of the set satisfactorily from optimum operation at three hundred meters (when cores IL are nearly completely withdrawn from their coils) to optimum operation at four hundred meters (when cores IL lie entirely within their coils). In Fig. 3, the input to the amplifier is diagrammatically indicated at the left at coil I, the output being at the telephones PH at the right.

In Figs. 1, 2 and 2^a, the longer or left-hand portion of primary PR is shown as connected to the plate of the tube. This is because this connection has been found to give the best results, although the reason is not clear. The winding is entirely operative, however, if the tube plate be connected to the smaller or right-hand portion of primary PR, i. e., to the right of reversal point X.

In Figs. 4 and 5 is shown a perfected form of construction of transformers embodying the above features. Here (instead of the varnished paper sheet construction of Fig. 1) an insulating form IF is provided for use in connection with separate coils termed "pies" or "pancakes" shown in Fig. 5. Form IF of Fig. 4 is a structure consisting of suitable insulating material fabricated to the shape shown, to leave annular slots for the reception of the pies for the primary and secondary windings. Form IF may, for example, be bakelite turned out in a lathe; but I prefer to mold form IF out of insulating material, such as any of the moldable materials on the market, including the shellac or bakelite class of moldable compounds. In Fig. 4, for example, the first slot at the left of form IF (Fig. 4) is filled with a pancake or pie coil PA (Fig. 5) constituting one of the seven pies of the primary winding. The second slot in form IF is filled by a secondary pie SA, constituting one of the seven pies of the secondary winding. The remaining slots of form IF are filled alternately with primary and secondary pies as shown.

One of the practical advantages of the transformer construction of Fig. 4 over that of Fig. 1 is that it permits winding of the coils independent of the laminated core IL, the pie coils being wound in the slots of form IF and thereafter core IL with its insulating support IS being slipped into the interior of form IF. Also form IF is interiorly shaped to conform to the rectangular cross section of laminated core IL; while the coil-slots in form IF may have any desirable bottom shape, as either circular, or preferably rectilinear in correspond-

ence with core IL. The opposition of magnetic fluxes in the transformer construction of Fig. 4 is obtained by the method shown in Figs. 4^a and 5, this method being the method of winding shown in Fig. 2 as the method employed in the transformer construction of Fig. 1. That is, in the transformer of Fig. 4 the first five pies of the primary (i. e., PA, PB, PC, PD and PE) are wound clockwise on form IF (like the left-hand portion of primary PR in Fig. 2); while from left to right beginning at reversal point X (Figs. 4, 4^a and 5) the remaining two pies of the primary (PF and PG) are wound anticlockwise, so that a straight connection between pies PE and PF, i. e., without any reverse connection, will cause an opposition of magnetic fluxes between the first five and the second two pies. In this case, as in the form of Figs. 1, 2 and 2^a, a much greater length of wire may be used without exceeding the desired wave length, and consequently a relatively large, strong wire can be employed for the primary winding. Heretofore it has been necessary in many cases (in order to provide the desired resistance damping) to use a nicrome wire as small as .0015 inch in diameter. By employing my methods, an ordinary commercial copper or nichrome wire of several mils diameter can be employed, without materially reducing the desired damping or increasing the inductance beyond the desired amount. Heretofore the necessary use of the very fine wire not merely increased the difficulties of (breakages during) manufacture, but resulted frequently (in the use of the transformer) in breakage of the fine wire by mechanical jar-rings of the set, thereby putting the latter out of operation. As a comparative example, a primary of a prior tube radio frequency amplifier transformer, consisting of nicrome wire .0015 inch in diameter and 12 feet long wound in 80 turns, may be replaced according to this feature of my invention by a primary of nichrome wire .003 inch in diameter and 35 feet long.

The transformers of Figs. 1 or 4 may be employed in either of the sets diagrammatically shown in Fig. 3, or in any other tube set where transformers are employed. These sets will be understood from the drawings, being of ordinary present construction and arrangement save for my improvements hereof. In Fig. 3 is shown a four-tube set in which the first three tubes are radio frequency amplifiers (RF¹, RF² and RF³), and the fourth tube is a detector P. In Fig. 6 is shown a six-tube set in which the first three tubes are radio frequency amplifiers, the fourth tube is a detector D, and the remaining two tubes are audio frequency amplifiers supplying the telephones PH. My improvements are most useful as the

radio frequency transformers of these sets (RT¹, RT² and RT³). As to the opposition of magnetic fluxes, this is most useful in the primary winding alone, as shown in Figs. 1 and 4, although it may be employed in the secondary alone, or in both primary and secondary, as will be illustrated.

In Fig. 6 is shown another form of transformer similar to that of Fig. 1, but with the primary wound with a plurality of reversals at the successive points of reversal X. At the left is a portion of seven turns, then a point X of reversal, and then a smaller portion of three turns before the next point of reversal X; and these portions are alternately of large and small portions, comprising seven portions as shown, four of which are large and three of which are small; but as in Fig. 1, one of the larger portions is connected to the plate of the tube. In a long winding, this provision of a larger number of reversed portions ensures the desired action of opposition of magnetic fluxes throughout the primary PR. It is believed that this transformer gives better all-around results than the forms of Figs. 1 and 4 where the primary is divided into only two reversed portions. In the transformers of Figs. 4 and 6, insulating supporting sheet IS may be mechanically extended to support a plurality of cores as shown in Fig. 3. In no case, however, need the sheet IS be insulating throughout its length, for, on the contrary, it may be mechanically strengthened by metal supports at portions of its length intermediate pairs of a core IL and a copper tube CT, being supported in any event in bearings B, Fig. 3, through which it can slide as actuated by the rack and pinion arrangement shown at the right. The right-hand rack portion, of course, is preferably of metal, mechanically connected to insulating portion of support IS.

In Fig. 7 is shown the method of obtaining the opposed portions of primary PR of Fig. 6 which is by the winding method illustrated in Figs. 2 and 4^a. In Fig. 4^a the pies are omitted from form IF for clearness, but the connections are shown, and they correspond with those of Fig. 5, the coils being shown in Fig. 5 for clearness in view of their omission from Fig. 4^a. Fig. 7 shows the method applied to Fig. 6 so clearly as not to require special description. In Fig. 7^a is shown the reverse connection method applied to the transformer of Fig. 6.

In Figs. 8 and 8^a is shown a form of my transformer construction wherein the entire winding is divided (as to reversed portions) into three equal portions, instead of two unequal portions as in Figs. 1 and 4, and of a plurality of unequal portions as in Fig. 6. In Figs. 8 and 8^a there are the same number of turns in each portion. This is a convenience in manufacture and provides a

symmetrical form of transformer. This is believed to be an advantageous alternative embodiment of the invention. The method of obtaining the opposition of magnetic fluxes is shown in Fig. 8 as by winding (the method shown in Figs. 2, 4^a and 7); and the method shown in Fig. 8^a is the method by connection (the method shown in Figs. 2^a and 7^a).

In Fig. 9 is shown one of my amplifier transformers wherein the method of opposition of magnetic fluxes is effected in both primary and secondary. In Fig. 9, the heavier lines represent primary PR and the lighter lines represent secondary SC. For clearness, the windings are shown without their support or core as in the case of other figures. In Fig. 9 the opposition of fluxes is obtained by the winding method, the left-hand portions of each of the primary and secondary being wound say clockwise, the middle portions say anticlockwise, and the right-hand portions clockwise, these portions commencing at the points of reversal X. In Fig. 9 the three portions are indicated as being equal of symmetrical as in Figs. 8 and 8^a. The form of Fig. 9 is believed to be advantageous for use in some cases such as those requiring increased damping in the secondary to provide for an increase of damping in the grid circuit of the succeeding tube to which the secondary is connected (see Figs. 3 and 6).

As to the above descriptions and diagrams of the flux-opposing arrangements, it will be understood, of course, that the directions are instantaneously relative, for the currents employed are oscillating currents such that the direction of current flow throughout any of the forms of transformers is reversed at each alternation of the oscillating current.

I claim:—

1. The improved oscillation-damping coupling-transformer system, which comprises a plurality of transformers each having windings possessing inductance and resistance for desired wave-length and damping of its circuits, and a core movable outwardly and inwardly of its said windings; means varying the wave-lengths of the circuits of the transformers by simultaneous movement of the several cores; at least one of the windings of each of the transformers having electrically opposed portions causing opposing magnetic fluxes permitting the desired damping of the system by the resistance of the wire of such winding without unduly increasing the length and effective inductance and wave-length of such winding; and a plurality of short-circuiting devices respectively mounted adjacent to and movable with the several cores thereby moving inwardly of the windings as the cores are moved outwardly and compensating for the loss of desirable damping of the trans-

former circuits by the outward core movements.

2. A circuit-damping transformer for coupling tuned oscillatory circuits, which comprises a core, and a movable support therefor permitting movement of the core outwardly of the transformer windings and varying the wave-length of the transformer; the windings having resistance for desired damping of their circuits; and a short-circuiting device also mounted on the said core-support adjacent the core thereon permitting movement of said device inwardly of the windings as the core is moved outwardly and thereby compensating for the loss of desirable damping of the transformer by the outward core movement.

3. A circuit-damping transformer for tuned oscillatory circuits, which comprises a core and a movable support therefor, and windings having inductance and resistance for desired wave-length and damping of their circuits; at least one of the windings comprising electrically opposed portions causing opposing magnetic fluxes which permit the desired damping by the resistance of the wire of the winding without unduly increasing the effective inductance and wave-length of such winding; and a short-circuiting device mounted on the core-support adjacent the core thereon and movable inwardly of the transformer windings as the core is moved outwardly, compensating for the loss of desirable transformer damping by the outward core movements.

4. The improved oscillation damping coupling transformer system, which comprises a plurality of transformers each having windings possessing inductance and resistance for desired wave-length and damping of their circuits and a core movable outwardly of the windings; said transformers each having at least one of its windings consisting of electrically opposed portions causing opposing magnetic fluxes permitting the desired damping by the resistance of the wire of the winding without substantially varying the effective inductance and wave-length; and means varying the wave-lengths of the transformer circuits by simultaneous movement of the several cores.

5. The improved oscillation damping coupling transformer system, which comprises a plurality of transformers provided with windings having inductance and resistance for desired wave-length and damping of their circuits and with a core movable outwardly and inwardly of its said windings; means varying the wave-lengths of the transformer circuits by simultaneous movements of said several cores; and a plurality of short-circuiting devices respectively mounted adjacent to and movable with the several cores thereby moving inwardly of the windings as the cores move outwardly and compensating for the loss of desirable damping of the system by the outward core movements.

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