

May 29, 1928.

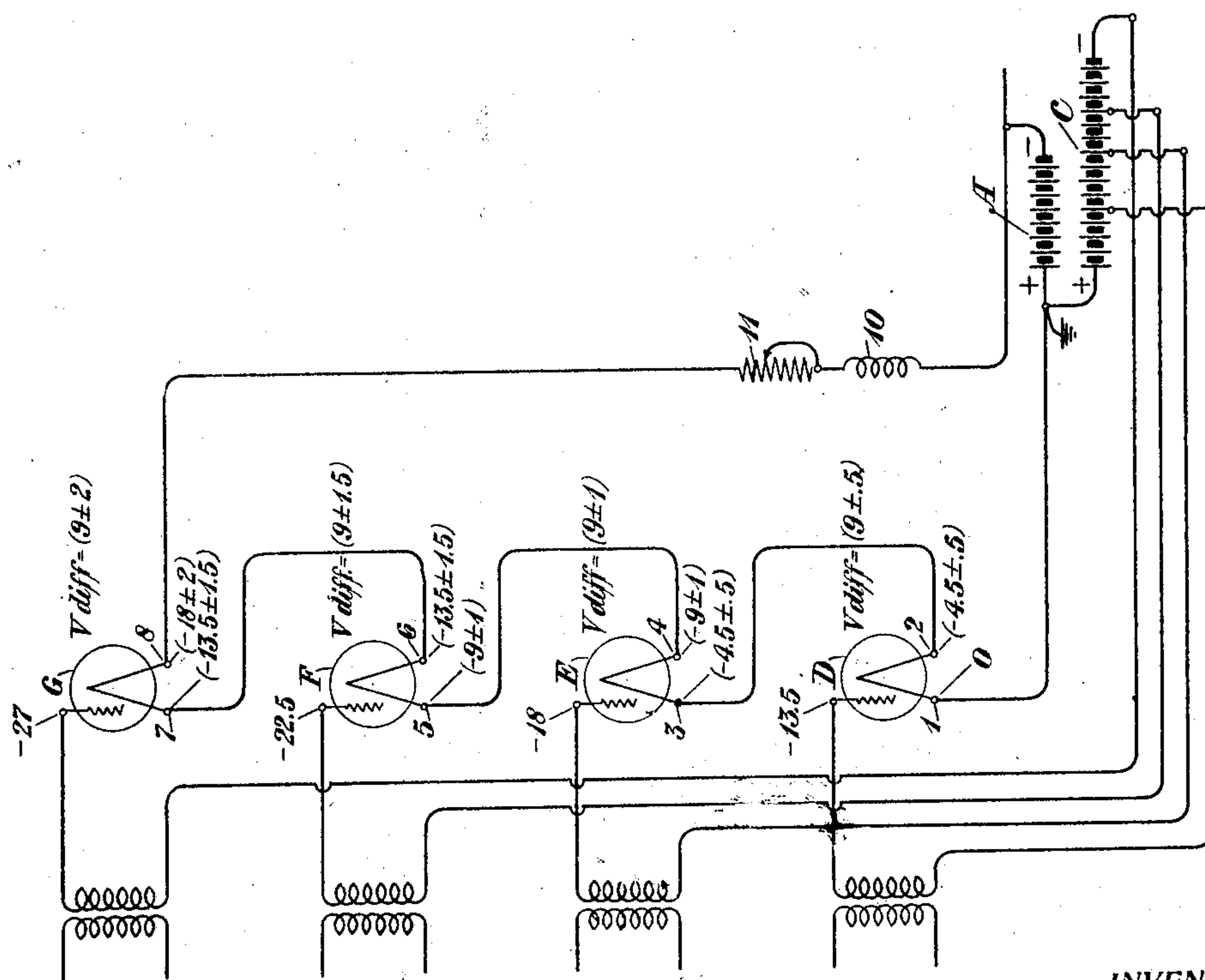
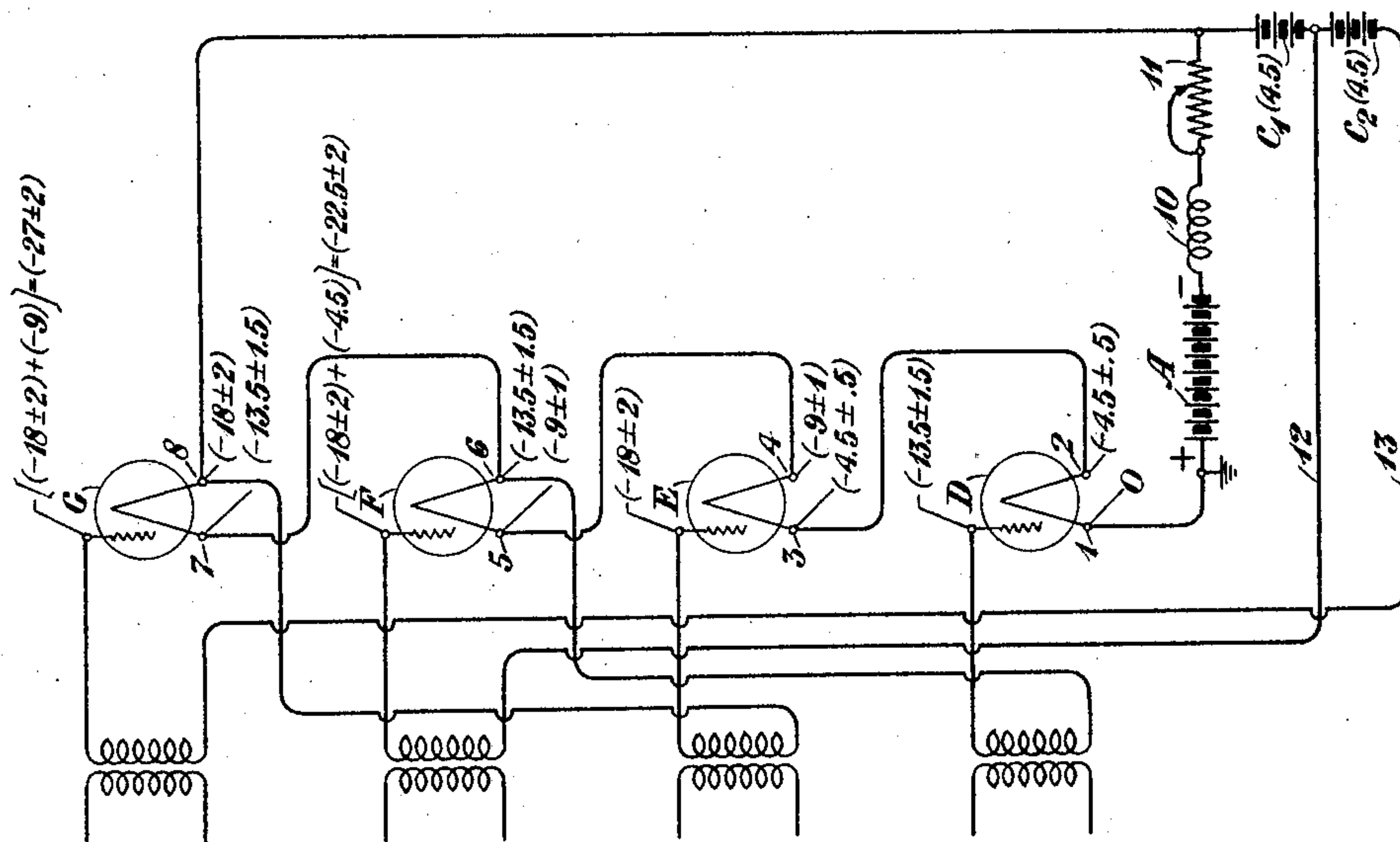
1,671,130

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GRID CIRCUITS OF ELECTRON TUBES

Filed May 16, 1923

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

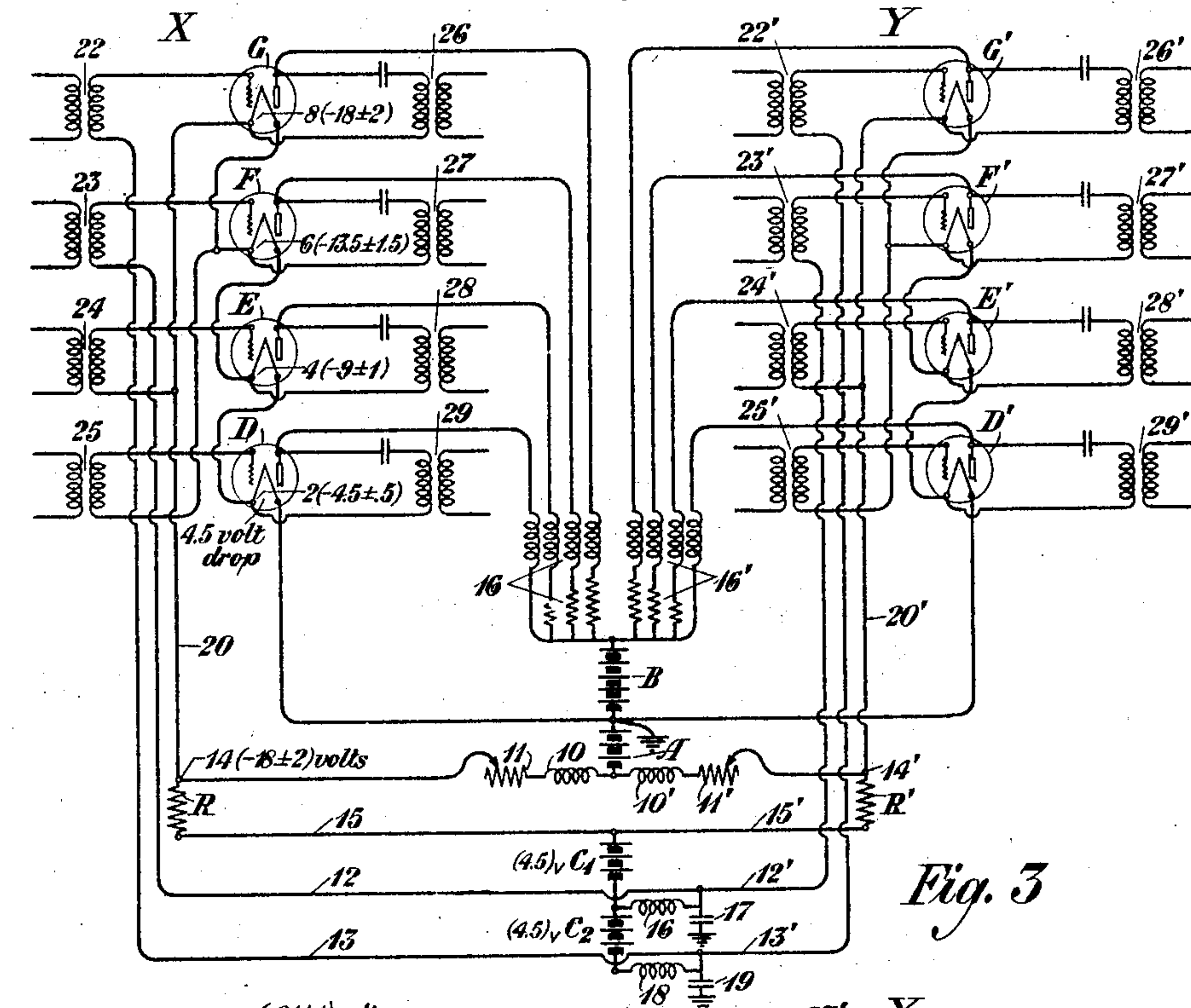


Fig. 3

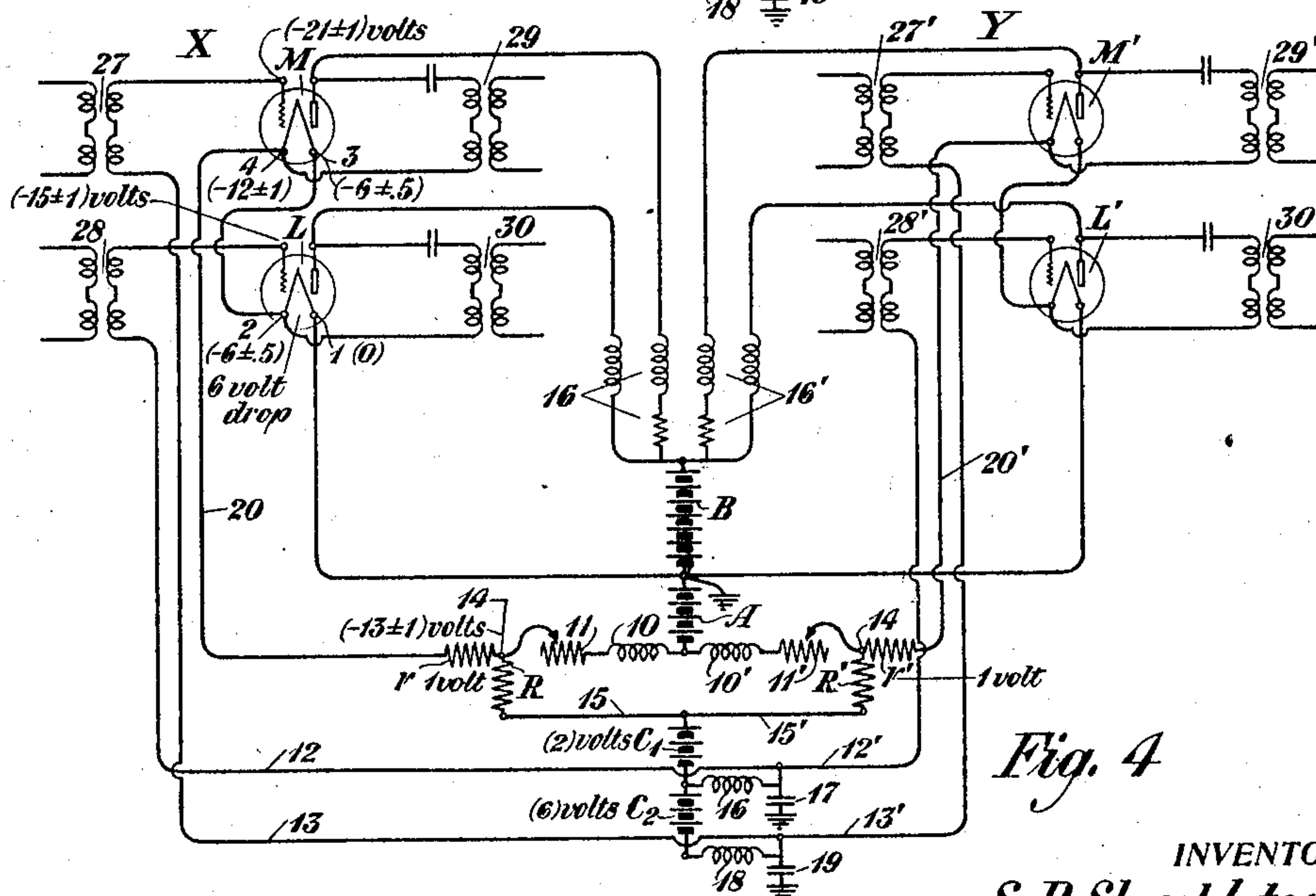


Fig. 4

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UNITED STATES PATENT OFFICE.

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GRID CIRCUITS OF ELECTRON TUBES.

Application filed May 16, 1923. Serial No. 639,419.

This invention relates to improvements in circuits for impressing potentials upon the grids of electron tubes and is particularly adaptable for use with electron tubes employed in telephone repeater circuits.

When electron tubes are used as amplifying elements in telephone repeaters the grid of each tube is usually maintained at negative potential with respect to the filament. A desirable potential difference between grid and filament has been found in many instances to be approximately 9 volts. In some instances the negative potential on the grid has been obtained by a small battery connected in the input circuit of the tube, a separate battery being used for each grid. In arrangements more recently developed the individual grid battery was done away with and the grids of all the repeater tubes of an installation were excited from a common battery. Such an arrangement is illustrated in the U. S. Patent No. 1,385,777 to A. B. Clark. In other arrangements the potential difference between the grids and filaments was provided for by circuits utilizing the potential drop in the filament circuit itself. In these last mentioned types of systems, namely those utilizing a common grid or C battery or those utilizing the potential drop in the filament circuit, it has been found that wider voltage variations may exist in the potential difference between grid and filament than are desirable. It is accordingly the general object of this invention to provide arrangements whereby the voltage variations in the desired potential difference between the grids and filaments will be reduced to a material degree and the operation of the tubes greatly improved. Other objects and features of the invention will appear more fully from the detailed description hereinafter given.

The invention may be more fully understood from the following description together with the accompanying drawing in the Figures 1, 2, 3 and 4 of which the invention is illustrated. In Fig. 1 are shown arrangements of the prior art and their disadvantages. In Figs. 2, 3 and 4 are shown circuit diagrams embodying this invention.

In Fig. 1 is shown an arrangement of the prior art in which a common C battery is provided for supplying potential to the grids. Such an arrangement is shown in detail in the aforementioned Patent No. 1,385,-

777 to A. B. Clark and reference may be had thereto for circuit details not illustrated therein. Four electron tubes D, E, F and G are shown having their filaments connected in series. The filament circuit may be traced as follows: from the negative terminal of battery A, through inductance 10 and resistance 11, through the filaments at tubes G, F, E and D in series, to the positive terminal of battery A. Resistance 11 is variable so that the filament current may be held constant and the coil 10 is highly inductive and thus prevents the disturbances on battery A from being transmitted to the talking circuits. Connected to points of different potential on the common C battery are conductors leading to the grids of each tube. For reasons which will be apparent it should here be noted that because of the series connection of the filaments the filament potential decreases from tube to tube due to the filament resistance, and if, for example, there is a 4.5 volt drop in each filament the lowest potential in the filaments of tubes D, E, F and G would be respectively -4.5, -9, -13.5 and -18 volts. As a 9 volt difference of potential between each grid and filament is desired the grids of tubes D, E, F and G respectively are connected to points on battery C of -13.5, -18, -22.5, and -27 volts. It has been found in practice, however, that the potential drop due to the filament resistance will not be exactly 4.5 volts but will vary for each filament so that it must be termed $4.5 \pm .5$ volts. If we now look at the series filament circuit with this variation in the filament drop in mind it will be seen that point 1 will have zero potential the potential of point 2 will be $(-4 \pm .5)$ volts, point 3 will be (-9 ± 1) volts, point 4 will be (-9 ± 1) volts due to the fact that the variation of both filaments will be cumulative, point 5 will be (-9 ± 1) volts, point 6 will be (-13.5 ± 1.5) volts due to the fact that the variation of the three filaments will be cumulative, point 7 will be (-13.5 ± 1.5) volts, and point 8 will be (-18 ± 2) volts due to the fact that the variation of the four filaments will be cumulative. With the aforementioned potential values for the grids it will be seen that this will result in a potential difference between grid and filament for tube D of $(9 \pm .5)$ volts, a potential difference for tube E of (9 ± 1) volts, and a potential difference for tube F

of (9 ± 1.5) volts and a potential difference for tube G of (9 ± 2) volts. It has been found in practice that a potential difference between grid and filament varying beyond the limits of (9 ± 1) volts is not desirable. Accordingly, with the above arrangements, while the tubes D and E might operate satisfactorily, the tubes F and G would not operate satisfactorily because the potential difference varied beyond desired limits. It is the purpose of this invention to provide arrangements whereby, when more than two tubes have their filaments in series, the voltage differences between grids and filaments of all the tubes will be kept from varying beyond the limit of (9 ± 1) volts, thereby ensuring the proper operation of all of the tubes.

In Fig. 2 is shown a circuit diagram illustrating schematically the arrangements of the invention. Similar reference characters have been used to denote like parts in both Figs. 1 and 2. Four electron tubes D, E, F and G are shown with their filaments connected in series in the following circuit: from battery A, inductance 10, resistance 11, through the filaments of tubes G, F, E and D in series to battery A. Resistance 11 is variable, so that the filament current may be held constant and the coil 10 is highly inductive and thus prevents disturbances on battery A from being transmitted to the talking circuits. The voltages at points 1, 2, 3, 4, 5, 6, 7 and 8, will be the same as heretofore pointed out with respect to Fig. 1 and are so marked on the drawing. A nine volt difference in potential between grids and filaments is desired. Accordingly the grid of tube D is connected as shown to point 6 which has a voltage of (-13.5 ± 1.5) . The voltage difference accordingly between grid and filament of tube D will be within the limits of (9 ± 1) volts, for if the voltage at point 2 is $(-4.5 + 1.5)$ the voltage of the grid will be $(-13.5 + 1.5)$ and if the voltage at point 2 is $(-4.5 - 1.5)$ the voltage of the grid will be $(-13.5 - 1.5)$. As has been pointed out with respect to Fig. 1, a voltage difference between grid and filament which remains within the limits of (9 ± 1) volts will insure satisfactory operation of the tube. The grid of tube E is connected as shown to point 8 and accordingly will have a potential of (-18 ± 2) volts. The voltage of the filament, as will be seen from point 4, will be (-9 ± 1) volts. Accordingly the voltage difference between grid and filament will be within the limits of (9 ± 1) volts, which will allow satisfactory operation of the tube. The grid of tube F will be connected over conductor 12 and through the battery C¹ to the point 14 of the filament circuit. Point 14 will have the same potential as point 8 which is (-18 ± 2) volts. The battery C¹ in this instance will have a volt-

age drop of 4.5 volts, although in other instances its voltage drop might be different. Accordingly the voltage of the grid of tube F will be $(-18 \pm 2) + (-4.5) = (-22.5 \pm 2)$. The voltage of the filament, as will be seen from point 6, will be (-13.5 ± 1.5) . Accordingly the voltage difference between grid and filament of tube F will be within the limits of (9 ± 1) volts, which will allow satisfactory operation of the tube. The grid of tube G will be connected over conductor 13 to battery C² and thence through battery C¹ to point 14. Battery C² in this instance will have a voltage drop of 4.5 volts although in other instances its voltage drop might be different. Accordingly the voltage of the grid of tube G will be

$$[(-18 \pm 2) + (-4.5) + (-4.5)] = (-27 \pm 2).$$

The voltage of the filament as will be seen from point 8 is (-18 ± 2) . Accordingly the voltage difference between grid and filament of tube G will be within the limits of (9 ± 1) volts, which will allow satisfactory operation of the tube. The invention in other words combines the feature of a common C or grid battery with that of utilizing the potential drop in the filament circuit itself so that the voltage difference between the grid and filament of each tube will remain the desirable limits of (9 ± 1) volts.

In Fig. 3 is shown an arrangement whereby a plurality of groups of tubes may have their grids supplied with potential in accordance with this invention. Similar reference characters have been used to denote like parts with respect to the other figures. The apparatus shown in the drawing comprises two groups X and Y of tubes or amplifiers for telephone circuits, each group comprising four independent talking circuits not shown in their entirety, but indicated merely by input transformers 22, 23, 24, 25 and 22', 23', 24', 25' and output transformers 26, 27, 28, 29 and 26', 27', 28', 29'. The talking circuits are associated with the electron tubes D, E, F, G and D', E', F', G'. The arrangements of the circuits are substantially the same as shown in Fig. 2. Each individual filament will cause a voltage drop of $(4.5 \pm .5)$ volts. Tubes D, E, F and G have their filaments connected in series as follows: from battery A, through filaments of tubes D, E, F and G in series, conductor 20, resistance 11, inductance 10 to battery A. Resistance 11 is variable so that the filament current may be held constant and coil 10 is highly inductive and thus prevents disturbances on the battery A from being transmitted to the talking circuits. The potentials of the filaments will be the same as heretofore pointed out with respect to Fig. 2 and are so indicated at points 2, 4, 6 and 8 of the drawing as $(-4.5 \pm .5)$, (-9 ± 1) , (-13.5 ± 1.5) and (-18 ± 2) volts respec-

tively. The grid of tube D is connected to point 6 so that it will have a potential of (-13.5 ± 1.5) volts and so that the voltage difference between grid and filament of the tube will be within the desired limits of (9 ± 1) volts. The grid of tube E is connected to point 8 so that it will have a potential of (-18 ± 2) volts and so that the voltage difference between grid and filament of the tube will be within the desired limits of (9 ± 1) volts. The grid arrangements of tubes D and E, it will be seen, are the same as already described with respect to Fig. 2. The grid of tube F will be connected over conductor 12, inductance 16, battery C_1 , conductor 15, resistance R, to point 14. Point 14 is connected by conductor 20 to point 8 and hence will have a potential of (-18 ± 2) volts. Battery C_1 will have a voltage drop in this instance of 4.5 volts. Accordingly the voltage of the grid of tube F will be (-22.5 ± 2) volts and the voltage difference between grid and filament of the tube will be within the desired limits of (9 ± 1) volts. As there is practically no current flow in this grid circuit the resistance R, which is relatively large, will cause no potential drop. The purpose of this resistance and also inductance 16 will be pointed out hereinafter. The grid of tube G will be connected over conductor 13, inductance 18, battery C_2 and battery C_1 , conductor 15, resistance R, to point 14. Battery C_2 in this instance will have a voltage drop of 4.5 volts. Accordingly the voltage of the grid of tube G will be (-27 ± 2) volts and the voltage difference between the grid and filament of the tube will be within the desirable limits of (9 ± 1) volts. The grid circuit arrangements of the tubes of set Y will be substantially the same as those heretofore described and no further description thereof will be given. The plate circuits of the tubes comprise the common B battery and the inductances and compensating resistances 16 and 16' and are substantially similar to the arrangements shown in the heretofore mentioned Patent 1,385,777 to A. B. Clark. As has been already pointed out the elements R and R' are of higher resistance but as practically no current flow exists in the grid circuits these elements will cause no potential drop therein. It is desirable that the potential at points 14 and 14' should in the arrangements shown remain fixed at (-18 ± 2) volts. If the resistances R and R' were not included in the arrangements and if one of the tubes of group Y should burn out or become otherwise defective, current from battery A would be supplied to point 14 through both coils 10 and 10' in parallel and thus tend to increase the voltage at point 14 beyond (-18 ± 2) volts. However the values of the resistances R' and R are so great that they practically prevent any current flow be-

tween points 14' and 14 over conductors 15' and 15, so that any variation in the Y set of tubes will cause no change in potential at point 14 and vice versa. Additional groups of tubes might have their grid potentials supplied in a similar manner from battery A. Elimination of interference between the various talking circuits is taken care of by providing a low impedance alternating current path to ground from the grid batteries as illustrated by the coils 16 and 18 and condensers 17 and 19.

In Fig. 4 is shown an alternative arrangement of the invention in which different types of tubes are utilized, such as tubes that have a 6 volt drop due to filament resistance rather than a 4.5 volt drop. Similar reference characters have been utilized to denote like parts with respect to the other figures of the drawing. The apparatus shown comprises two groups X and Y of tubes or amplifiers for telephone circuits, each group comprising two independent talking circuits not shown in their entirety but indicated merely by input transformers 27, 28, and 27', 28', and output transformers 29, 30, and 29', 30'. The talking circuits are associated with electron tubes L, M and L', M'. The filament circuits for tubes L and M may be traced as follows: from battery A, through the filaments of tubes L and M in series, conductor 20, resistance r and resistance 11, inductance 10 to battery A. Point 1 of tube L will have a potential of zero. Due to the filament resistance point 2 of tube L will have a potential of $(-6 \pm .5)$ volts. Point 3 of tube M will have a potential of $(-6 \pm .5)$ volts. Point 4 of tube M due to the filament resistance of both tubes will have a potential of (-12 ± 1) volts. The resistance r is designed to cause a drop in the voltage of 1 volt. Accordingly point 14 will have the voltage of point 4 plus the drop caused by resistance r or in other words a potential of (-13 ± 1) volts. The grid of tube L will be connected over conductor 12, coil 16, battery C_1 , conductor 15, resistance R, to point 14. Battery C_1 in this instance will have a voltage of 2 volts. Accordingly the voltage of the grid of tube L will be $(-13 \pm 1) + 2$ or in other words (-15 ± 1) volts. The difference in potential between grid and filament of tube L will thus be within the desirable limits of (9 ± 1) volts. The grid of tube M will be connected over conductor 13, coil 18, battery C_2 , battery C_1 , conductor 15, resistance R, to point 14. Battery C_2 in this instance will have a voltage of 6 volts. Accordingly the voltage of the grid of tube M will be $(-6) + (-2) + (-13 \pm 1)$ or in other words (-21 ± 1) volts. The difference in potential between grid and filament of tube M will thus be within the desirable limits of (9 ± 1) volts. The circuits for the tubes of group Y are substantially the same as

those already described. In other respects the circuit arrangements of Fig. 4 are similar to those of Fig. 3 and no further description thereof will be given.

5 While the invention has been disclosed in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and widely varied forms without departing from the spirit of the invention as defined by the ap-
10 pended claims.

What is claimed is:

1. A plurality of electron tubes, a circuit connecting the filaments of said tubes in series, conductors leading to the grids of cer-
15 tain of said tubes and being connected to said filament circuit at a point thereon of predetermined potential and means in said conductors comprising resistances of the fila-
20 ments alone to cause a drop in the voltage applied thereto from said filament circuit.

2. A plurality of sets of electron tubes, a filament battery, circuits associated with said battery and connecting the filaments of
25 each of said sets of tubes in series, conductors leading to the grids of certain of the tubes of each set and being connected to said filament circuits at points thereon of predetermined potential and means in said con-
30 ductors comprising resistances of the filaments alone to cause a drop in the voltage applied to said grid conductors from said filament circuits.

3. A plurality of sets of electron tubes, a
35 filament battery, circuits associated with said battery and connecting the filaments of each of said sets of tubes in series, conductors leading to the grids of certain of the tubes of each set and being connected to said

filament circuits at points thereon of pre- 40
determined potential, a grid battery, and means for associating said grid battery with said conductors so as to cause a drop in the voltage applied thereto from said filament
45 circuits.

4. A plurality of sets of electron tubes, a filament battery, circuits associated with said battery and connecting the filaments of each of said sets of tubes in series, conduc-
50 tors leading to the grids of certain of the tubes of each set and being connected to said filament circuits at points thereon of predetermined potential, a grid battery, means for associating said grid battery with said con-
55 ductors so as to cause a drop in the voltage applied thereto from said filament circuits, and an alternating current path to ground associated with said grid battery.

5. A plurality of sets of electron tubes, a filament battery, circuits associated with said
60 battery and connecting the filaments of each of said sets of tubes in series, a conductor connected to each of said filament circuits at points thereon of the same predetermined
65 potential, a pair of relatively high resistance elements included in said conductor, conductors leading to the grids of certain of the tubes of each set and being con-
70 nected to said last mentioned conductor at a point between said resistance elements, and means in said conductors to cause a drop in the voltage applied thereto from said last mentioned connecting point.

In testimony whereof, I have signed my name to this specification this 15th day of
75 May 1923.

SAMUEL P. SHACKLETON.