Oct. 27, 1931. J. H. PRESSLEY 1,829,058

HIGH FREQUENCY TRANSFORMER

Filed Aug. 3, 1929 2 Sheets-Sheet 1

Fig. 1,

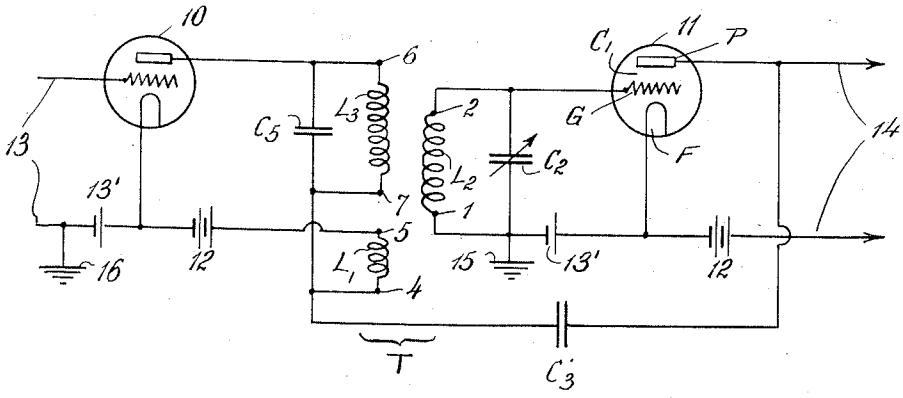


Fig. 2,

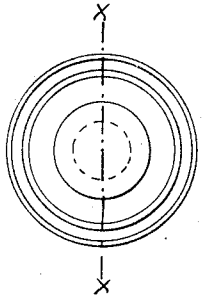
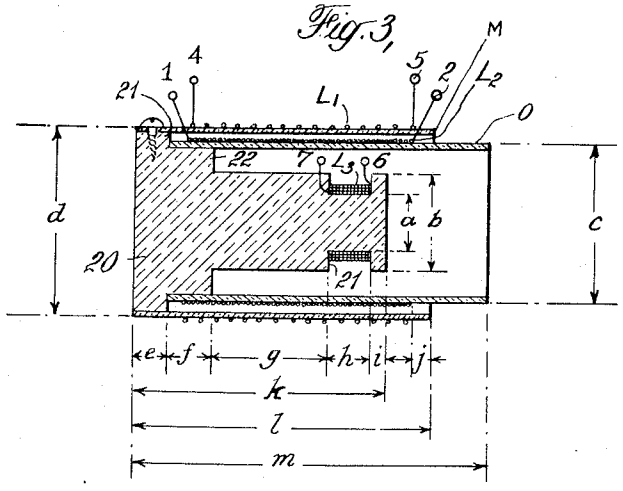


Fig. 3,



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Fig. 4,

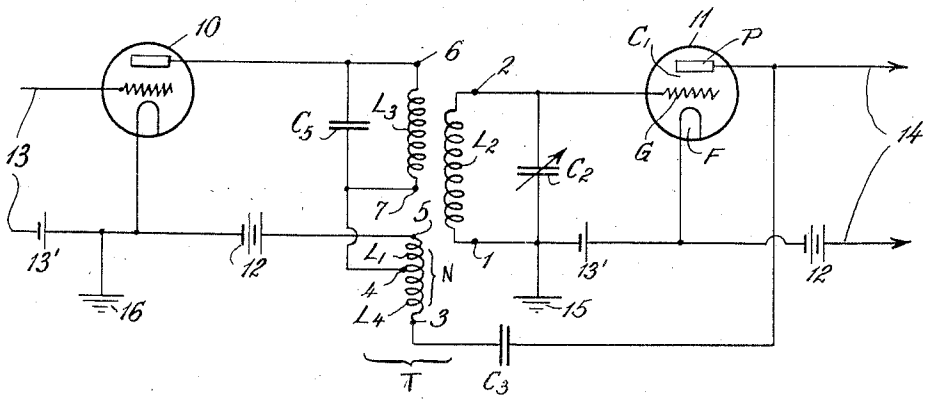


Fig. 5,

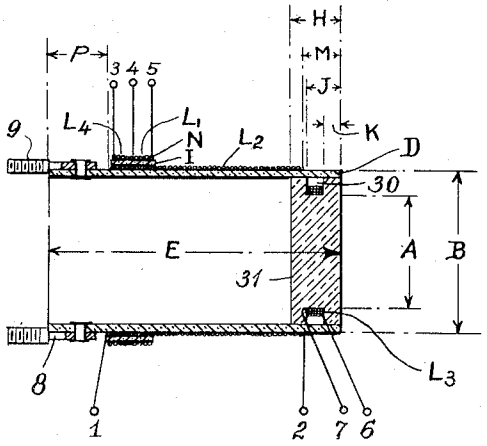
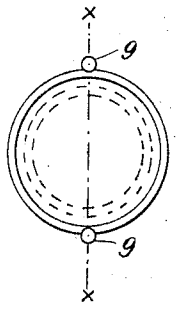


Fig. 6,



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HIGH FREQUENCY TRANSFORMER

Application filed August 3, 1929. Serial No. 383,214.

This invention relates to high-frequency transformers, and more particularly to transformers of this type which are utilized as an essential part of coupling networks adapted to provide substantially uniform amplification over a desired frequency range when interconnecting the successive tubes of a high-frequency thermionic amplifier.

An object of the invention is to provide structural features of high-frequency transformers which accomplish the above results with high efficiency.

A second object of the invention is to provide transformers of the above type which, in addition to their function of providing substantially uniform amplification over a frequency range, are also adapted, when utilized in conjunction with a suitable capacity element, for neutralizing the effect of the grid-to-plate interelectrode capacity electrostatically coupling the grid and plate circuits of a thermionic amplifier.

The subject of uniform gain coupling networks of the type mentioned above is described fully in application for United States Letters Patent Serial No. 120,045, filed July 2, 1926, and United States Letters Patent 1,763,380, issued June 10, 1930, both in the name of C. E. Trube, which descriptions are made a part of the present specification. Since the present invention is limited to transformers suitable for use in coupling networks, the circuits adapted to accomplish substantially uniform gain in thermionic amplifier circuits will be referred to herein only so far as is necessary to point out the features of the present invention.

Referring to the drawings, Fig. 1 shows in circuit diagram form two thermionic amplifier tubes interconnected by a uniform gain coupling network employing one of the novel transformers of the present invention. The circuit of Fig. 1 is identical with that disclosed in Fig. 6 of the drawings accompanying the Trube patent referred to above, except for the addition of the neutralizing capacity C_3. For convenience in comparing the two drawings the circuit elements have been similarly designated.

Figs. 2 and 3 disclose the structural details of a novel transformer of the present invention which transformer is shown schematically in Fig. 1. Fig. 2 shows an end elevation of the transformer as viewed from the right of Fig. 3, while Fig. 3 shows a cross-section thereof taken along the line x—x of Fig. 2.

Fig. 4 shows a circuit diagram similar in scope to Fig. 1 but employing a slightly modified type of transformer.

Figs. 5 and 6 disclose the structural details of a transformer of the type disclosed schematically in Fig. 4. Fig. 6 shows an end elevation of the transformer as viewed from the left of Fig. 5; while Fig. 5 shows a cross-section thereof taken along the line x—x of Fig. 6.

Referring now to Fig. 1, a pair of thermionic tubes 10 and 11, each having grid G, plate P and filament F electrodes, are connected in cascade by means of a uniform gain coupling network comprising transformer T and capacities C_2 and C_5. Batteries 12 provide the necessary direct current to the plate circuits of the tubes, while batteries 13′ provide negative grid biasing potential. The transformer T comprises a secondary winding L_2 and a pair of primary windings L_1 and L_3. The secondary winding shunted by a variable tuning capacity C_2 is connected between grid and filament of tube 11. The primary winding L_3, shunted by the fixed capacity C_5, is connected series opposing with the primary winding L_1 between the plate and filament of tube 10. The winding L_3 contains relatively many turns and hence a high inductance compared to L_2; the winding L_1 has only a few turns compared to L_2 and hence a low relative inductance. The circuit L_3 C_5 is resonant to a frequency slightly below the lowest frequency within the tuning range of capacity C_2, so that this parallel circuit has an impedance which decreases with increase in frequency over the tuning range, whereas, L_1 has an impedance which increases with frequency. The windings L_1 and L_3 are connected in opposite directions, but produce additive effects in the winding L_2 due to the fact that over the operating frequency range the currents therein are opposite in phase and

hence produce additive magnetic fields. By suitably proportioning the various elements of the coupling network, the uniform gain coupling is obtained as described in the Trube application and patent referred to above.

In order to neutralize the interelectrode coupling capacity C_1 occurring between the plate and grid of tube 11, a neutralizing capacity C_3 is connected from the plate P of tube 11 to a point between the primary windings L_1 and L_3. With the circuit arrangement shown and with winding L_1 properly poled with respect to winding L_2, neutralization is attained when the following relation holds true.

$$(1) \quad \frac{C_3}{C_1} = \frac{L_2}{M_{1-2}}$$

where M_{1-2} is the mutual inductance between the windings L_1 and L_2. Under the conditions of Equation (1) stated, a current flowing from the plate to grid thru the coupling capacity C_1 due to a disturbance initiated in the plate circuit will set up a magnetic flux in secondary winding L_2 which is equal and opposite to the flux produced therein as a result of the current simultaneously flowing thru neutralizing capacity C_3 and neutralizing winding L_1, with the result that no voltage will be induced between the grid and filament of tube 11 due to such a disturbance in the plate circuit.

In order to have the neutralization of the plate-to-grid capacity C_1 effective over the entire tuning frequency range of the capacity C_2, it is necessary to have as close a magnetic coupling as possible between windings L_1 and L_2. Furthermore, in order that the neutralization thus obtained be not disturbed by the primary circuit associated with tube 10, it is required that the coupling between windings L_1 and L_3 be as loose as possible consistent with the necessary degree of coupling between windings L_2 and L_3. It has been found that the uniform gain coupling network operates most satisfactorily when the coupling between windings L_2 and L_3 is not too loose and not too close, i. e., when the coupling is about 15% to 20%, which might be termed a moderate degree of coupling. Since a coupling of about 70% is, in practice, obtainable between windings L_1 and L_2, it is possible to have the degree of coupling between windings L_1 and L_3 amount to only a few percent by suitably positioning windings L_1 and L_3 relative to L_2 in the manner explained below. This latter is a very desirable condition since, as was explained above, it prevents disturbances of the neutralization due to currents in the primary circuit.

From what has been stated above, it will be seen that the transformer T must be designed to meet a number of conditions which may be summarized as follows. The inductance L_3 must be large, and the inductance L_1 small relative to L_2. The coupling between L_2 and L_3 must be of the order of 20%, and that between L_1 and L_2 as close as possible, say around 70%, while that between L_1 and L_3 must be loose and of the order of only a few percent. These ideal coupling conditions are mutually at variance so that special placing of the coil windings is required for obtaining the best compromise result.

Referring now to Figs. 2 and 3, a coil is shown which meets the above conditions in a highly efficient manner. Referring more particularly to Fig. 3, the transformer comprises a spool 20 of insulating material preferably of wood, such as maple, which spool has a sharply constricted portion 21 adjacent one end for reception of the primary winding L_3 which comprises an annular winding of a plurality of layers. At its opposite end, the spool 20 has formed thereon a pair of shoulders 21 and 22 of different diameters arranged in step-like relation. A tubular section O of insulating material, such as bakelite, or the like, is adapted to have one end snugly fitted around the shoulder 22 of smaller diameter formed on the spool 20, and is of such length as to extend considerably beyond the constricted end of the spool 20, as shown. The secondary winding L_2 comprises a single layer of wire uniformly wound about the tubular section O commencing at a point adjacent the shoulder 22 and extending somewhat beyond the winding L_3.

The arrangement shown, wherein the winding L_3 has a diameter considerably less than that of the winding L_2 and is positioned coaxially therewithin, permits a moderate degree of magnetic coupling, say of the order of 15% to 20%, to be obtained between the windings L_2 and L_3.

A second tubular section M of insulating material, preferably stiff paper, has one end fitted snugly about the shoulder 21 of spool 20, the tubular section being of such length as to extend beyond the constricted end of the spool 20, but not so far as the tubular section O. This arrangement, wherein the secton O projects beyond the section M, permits section O to be easily grasped and removed in order to repair any defects in the winding L_2.

The small primary winding L_1 is wound about the tubular section M and comprises a single layer of wire uniformly wound substantially between the limits of the winding L_2.

Windings L_1 and L_2, as will be seen from the dimensions given below, are of only slightly differing diameters so that with the coaxial positioning of the windings as shown, wherein winding L_2 is positioned within winding L_1, a high degree of magnetic coupling is obtained between the two. Furthermore, by positioning windings L_1 and L_3 on

opposite sides of winding L_2 in the manner shown, it is possible to obtain the required close degree of coupling between L_1 and L_2, and the moderate degree of coupling required between L_2 and L_3, while at the same time permitting a relatively small degree of coupling between windings L_1 and L_3 which, as was pointed out above, is a necessary condition.

The dimensions of a coil of the type shown in Fig. 3 which has proved highly efficient in practice are given in the following table. The various lengths given are designated in Fig. 3 by the small letters.

$a = \frac{7}{16}$ inch
$b = \frac{3}{4}$ inch
$c = 1\frac{1}{4}$ inches
$d = 1\frac{7}{16}$ inches
$e = \frac{1}{4}$ inch
$f = \frac{3}{8}$ inch
$g = \frac{7}{8}$ inch
$h = \frac{5}{16}$ inch
$i = \frac{1}{8}$ inch
$j = \frac{1}{8}$ inch
$k = 1\frac{15}{16}$ inches
$l = 2\frac{5}{16}$ inches
$m = 2\frac{1}{2}$ inches
$n = \frac{1}{4}$ inch
M = .025 inch paper
O = $\frac{1}{16}$ inch bakelite

The data on the windings is as follows:

Winding L_1 comprises 14½ turns of #36 B. & S. gauge D. S. C. wire uniformly wound over a length of 1¾ inches.

Winding L_2 comprises 135 turns of #28 B. & S. gauge enameled wire uniformly wound over a length of 1¾ inches.

Winding L_3 comprises 220 turns of #36 B. & S. gauge D. S. C. wire having a length of $\frac{5}{16}$ inch uniformly wound in a sufficient number of layers to provide the specified number of turns.

The following electrical measurements were obtained at 1,000 cycles for a transformer having the specifications given above. The self-inductances of the windings expressed in microhenrys were as follows:

Winding L_1=4.3 microhenrys
Winding L_2=252 microhenrys
Winding L_3=500 microhenrys

the mutual inductances were;

M_{1-2}=23 microhenrys
M_{2-3}=67.3 microhenrys

where M designates the mutual inductance, and the subscript denotes the windings between which the mutual is given, i. e., M_{1-2} equals the mutual inductance between windings L_1 and L_2, etc. The coefficient of magnetic coupling K_1, between windings L_1 and L_2 was 70%, and the corresponding coefficient between L_2 and L_3 was 19%. Referring for a moment to Fig. 1, the capacity C_5 equals 250 mmf. The resonant frequency of the primary circuit L_3 C_5 with such inductance and capacity values is 450 kc., and the maximum required capacity range of the tuning condenser C_2 is from 40 to 350 mmf. adapted to tune the coupling network over a range of from about 550 to 1500 kc. A neutralizing capacity C_3 of about 85 mmf. was required for a "UX226" type vacuum tube having a grid-plate capacity C_1 of about 7 mmf. The transformer is designed for use in a copper or aluminum shielding can of a diameter of 2⅜ inches and length of 3 inches, and the above electrical constants for the transformer are given with the same mounted in such a can.

Fig. 4 shows a circuit arrangement utilizing a slightly modified type of transformer from that shown diagrammatically in Fig. 1. In Fig. 4, in order to utilize a neutralizing capacity C_3 of approximately 60 mmf. in conjunction with the same type of tube, it is required that the neutralizing winding have a larger inductance than that of the small primary winding L_1. To accomplish this a winding L_4 comprising a few turns is interposed between the neutralizing capacity C_3 and the connection to winding L_1. Otherwise the circuit arrangement of Fig. 4 is similar to that of Fig. 1.

Fig. 5 discloses the structural details of the transformer T shown diagrammatically in Fig. 4. Referring to Fig. 5, the large primary winding L_3 comprising an annular coil of several layers is wound in a circumferential groove 30 formed in a spool 31 of suitable insulating material, preferably impregnated wood. A suitable tubular section D of insulating material, preferably bakelite, has one end fitted snugly around the spool 31 as shown. The secondary winding L_2 comprising a single layer is uniformly wound about the tubular section D from a point adjacent the winding 30 to a point some distance therefrom. A thin strip of insulating material I, preferably celluloid, is wrapped snugly about the winding L_2 adjacent the end thereof distant from winding L_3, and a neutralizing winding N comprising a single layer of relatively few turns is wound snugly about the celluloid strip I. This winding N terminates in terminals 3 and 5 and has an additional terminal 4 tapped at an intermediate point for forming the winding L_1 and L_4. Mounting lugs 9 and 10 are suitably affixed to the tubular section D.

By positioning the winding L_3 coaxially with winding L_2 and adjacent one end thereof, a moderate degree of magnetic coupling is obtained between the windings. A close degree of magnetic coupling is obtained between winding L_2 and windings L_1 and L_4 due to the close physical proximity of the two. The required small degree of magnetic coupling between windings L_3 and N and

is obtained by associating these windings with opposite ends of the winding L_2, and also by making L_3 of smaller and L_1 and L_4 of larger diameter than L_2.

The following dimensions were utilized in a successful coil of the type shown in Fig. 5 where the capital letters designate in Fig. 5 the dimensions given;

A = 7/8 inch
B = 1 1/4 inches
D = 1/16 inch bakelite
E = 2 1/2 inches
H = 3/8 inch
I = .01 inch celluloid
J = 1/4 inch
K = 1/8 inch
M = 9/32 inch
P = 1/2 inch

The electrical constants of the transformer when placed in a cylindrical copper can having a 2 3/8 inch diameter and a length of 3 inches and measured at 1,000 cycles, were as follows: For self-inductances of the windings expressed in microhenrys:

L_1 = 6.9 microhenrys
$L_1 + L_4$ = 36.4 microhenrys
L_2 = 245 microhenrys
L_3 = 1710 microhenrys

The mutual inductances were:

M_{1-2} = 16.3 microhenrys
M_{N-2} = 42.5 microhenrys
M_{2-3} = 92.5 microhenrys

The coupling coefficient between the small primary L_1 and the secondary L_2 was 40.2 percent, between the neutralizing winding N and L_2 is 63 percent, and between the large primary L_3 and the secondary L_2 was 15 percent.

The winding data is as follows:

The large primary winding L_3 consists of 270 turns of #36 B. & S. gauge D. S. C. wire.

The secondary winding L_2 comprises 131 turns of #28 B. & S. gauge enameled wire.

Winding L_1 comprises 18 turns and L_4 comprises 9 3/4 turns of #36 B. & S. gauge D. S. C. wire.

In either of the foregoing coil designs, L_3 can have the alternative construction of the so-called "universal" type of multi-layer coils.

I claim:

1. A high-frequency transformer comprising a secondary distributed cylindrical winding, a first primary distributed cylindrical winding of few turns relative to and closely wound about the secondary for providing a high degree of magnetic coupling therewith, and a second primary annular winding of compact structure of many turns relative to and positioned within said secondary and of sufficiently smaller diameter than said secondary to provide a moderate degree of magnetic coupling therewith, the aforesaid couplings between said primary and secondary windings being obtainable consistent with a relatively low degree of magnetic coupling between said primary windings resultant upon the positioning thereof on opposite sides of said secondary winding.

2. A high-frequency transformer comprising in combination a spool of insulating material having a sharply constricted portion adjacent one end thereof for reception of a compact annular winding positioned therein, said spool having formed at the opposite end thereof from said constricted portion a pair of shoulders of different diameters in stepped relationship, a tubular section of insulating material fitted about said shoulder of smaller diameter and extending beyond the opposite end of said spool, a distributed winding wound uniformly about said tubular section from a point adjacent said last mentioned shoulder to a point beyond said annular winding, a second tubular section of insulating material fitted about said shoulder of larger diameter and extending beyond the opposite end of said spool, and a distributed winding wound uniformly about said second tubular section substantially within the limits of the distributed winding first mentioned.

3. A high-frequency transformer comprising in combination a tubular section of insulating material, a first distributed winding comprising a single layer wound uniformly about said section between certain limits thereof, a second tubular section of insulating material of larger diameter than the first and surrounding the same, a second distributed winding of few turns relative to said first winding wound uniformly about said second tubular section substantially within the limits of said first distributed winding, a spool of insulating material of smaller diameter than said tubular section first mentioned and positioned within the same, said spool having a sharply constricted portion for reception of a compact annular winding wound thereabout of many turns relative to said first winding, and means for maintaining said windings positioned as aforesaid in fixed spacial relationship.

4. A high-frequency transformer adapted for use in a uniform gain coupling network associated with the input to a thermionic tube having grid filament and plate electrodes, comprising in combination, a distributed cylindrical secondary winding, a first distributed cylindrical primary winding of few turns relative to and closely wound about said secondary for providing a high degree of magnetic coupling therewith, and a second compact annular primary winding of many turns relative to and positioned within said secondary and of sufficiently

smaller diameter than said secondary to provide a moderate degree of magnetic coupling therewith, the aforesaid couplings between said primary and secondary windings being obtainable consistent with a relatively low degree of magnetic coupling between said primary windings as compared with the degree of coupling between each primary winding and the secondary winding, resultant on the positioning thereof upon opposite sides of said secondary winding.

5. A high-frequency transformer comprising first and second primary windings and a secondary winding, said first primary winding being positioned within said secondary and said second primary winding being wound over said secondary winding, the distance between said first primary winding and said secondary winding being considerably greater than the distance between said second primary winding and said secondary winding, whereby the coefficient of coupling between said second primary winding and said secondary winding is considerably greater than the coefficient of coupling between said first primary winding and said secondary winding, and whereby the coefficient of coupling between said first and second primary windings is substantially less than the coefficient of coupling between said first primary winding and said secondary winding.

6. A high-frequency transformer comprising first and second primary windings and a secondary winding, said first primary winding being positioned within said secondary, and said second primary winding being wound over said secondary winding, the distance between said first primary winding and said secondary winding being considerably greater than the distance between said second primary winding and said secondary winding, whereby the coefficient of coupling between said first primary winding and said secondary winding is considerably greater than the coefficient of coupling between said first and second primary windings, and the coefficient of coupling between said first and second primary windings is substantially less than the coefficient of coupling between said second primary winding and said secondary winding.

7. A high-frequency transformer according to claim 6 in which the coefficient of coupling between said second primary winding and said secondary winding is about 70 per cent, and the coefficient of coupling between said secondary winding and said first primary winding is about 20 per cent, and the coefficient of coupling between said first and second primary windings is less than 8 per cent.

8. A high-frequency transformer comprising first and second primary windings and a helical secondary winding, the first of said primary windings being located within said secondary winding, the second of said primary windings being located outside said secondary winding, said first primary winding being a compactly wound multi-layer winding having a higher inductance than said secondary winding and placed a substantial distance inside said secondary winding, and said second primary winding being of lower inductance than said secondary winding and being helically wound over and very close to said secondary winding, whereby the coefficient of coupling between said second primary and said secondary windings is much higher than the coefficient of coupling between said first primary and said secondary windings, and the coefficient of coupling between said first and second primary windings is much lower than that between said first primary and said secondary windings.

9. A high-frequency transformer adapted to couple a source of high-frequency signals to the input of a space discharge device which comprises a cathode, anode and control electrode, said device having undesirable capacity between said anode and said control electrode and being provided with a condenser connected to said anode for neutralizing said undesirable capacity, said transformer comprising first and second primary windings for connection in series with said source, a secondary winding for connection to said cathode and control electrode, said secondary winding being helically wound, said first primary winding being compactly wound and located at a substantial distance within said secondary winding, said second primary winding being helically wound directly over, and close to, said secondary winding, whereby the degree of coupling between said second primary winding and said secondary winding is close and the coupling between said first and second primary windings is very loose, relative to the coupling between said secondary winding and said first primary winding and whereby said second primary winding is adapted to provide proper potential to said neutralizing condenser to neutralize said undesired capacity.

10. A high-frequency transformer adapted to couple a source of high-frequency signals to the input of a space discharge device containing an anode, cathode and grid and to provide the proper potential to effect grid circuit neutralization of the anode-grid capacity of said device, said transformer comprising first and second primary windings for connection in series with said source, a secondary winding for connection to said cathode and said grid, said secondary winding being wound in a single layer on a cylindrical form, said second primary winding being wound in a single layer on a second cylindrical form surrounding said secondary winding, and said second primary winding

having fewer turns than, and being located close to, said secondary winding whereby the degree of coupling between said second primary winding and said secondary winding is close, said first primary winding being compactly wound in a spool situated at a substantial distance within said secondary winding and having a greater number of turns than said secondary winding, whereby the coupling between said first primary winding and said secondary winding is moderate and whereby the proper potential is developed across said second primary winding to effect said neutralization.

In testimony whereof I affix my signature.

JACKSON H. PRESSLEY.