April 5, 1949. H. KLEMPERER 2,466,028

CONTROLLED PEAKING TRANSFORMER

Original Filed Aug. 2, 1940 4 Sheets-Sheet 1

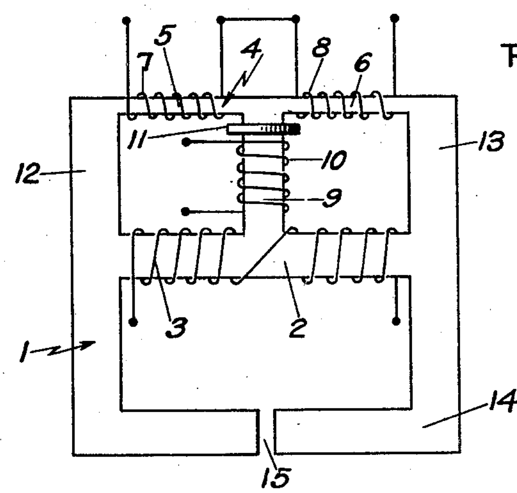


FIG. 1.

FIG. 2.

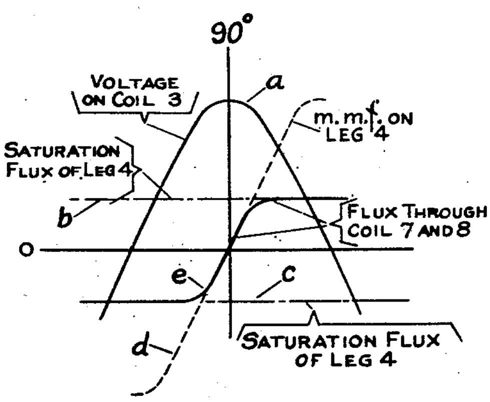


FIG. 3.

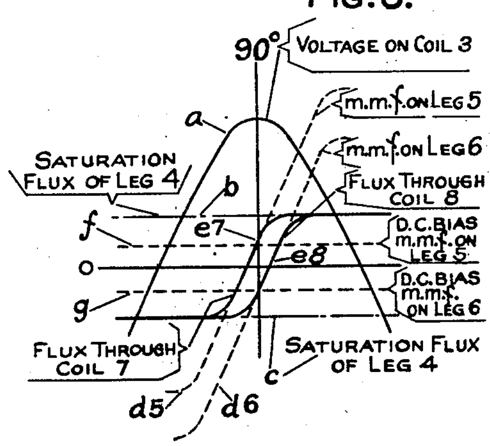


FIG. 2a

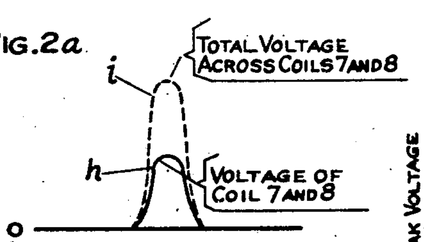
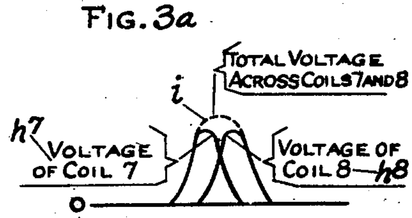
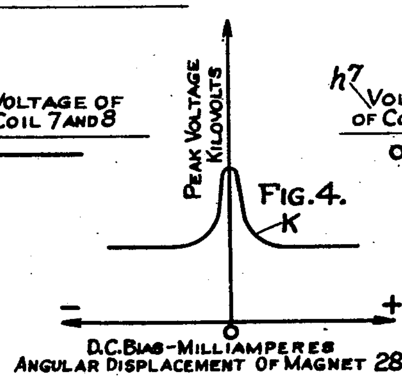


FIG. 3a





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CONTROLLED PEAKING TRANSFORMER

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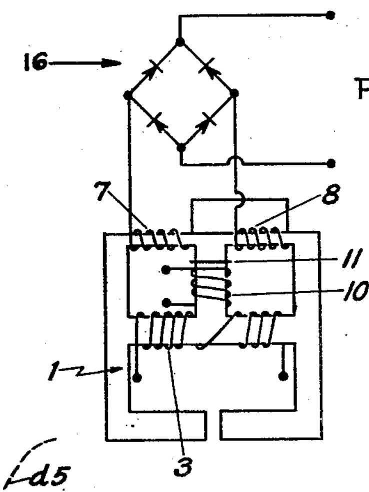

FIG. 5.

FIG. 6.

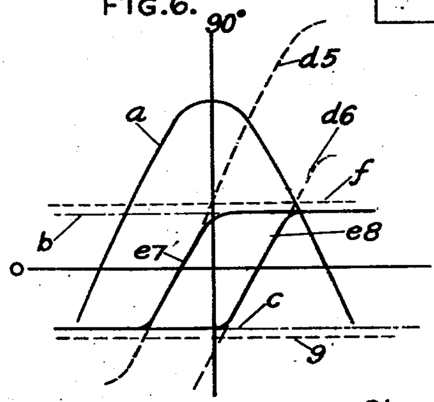

FIG. 6b.

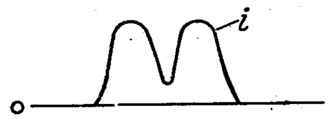

FIG. 6a.

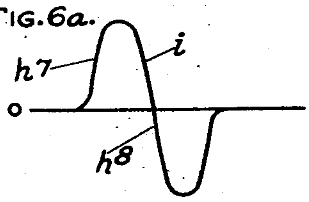

FIG. 7.

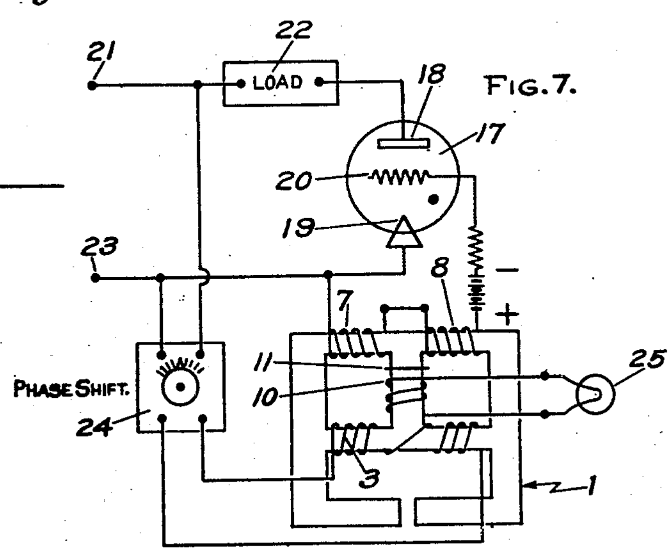

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FIG. 8.

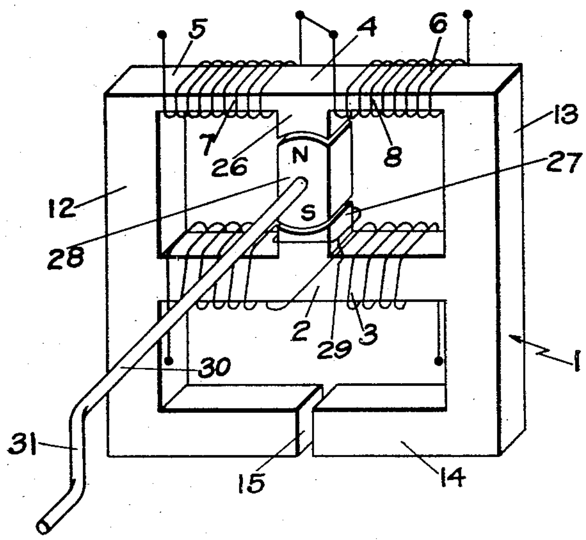

FIG. 9.

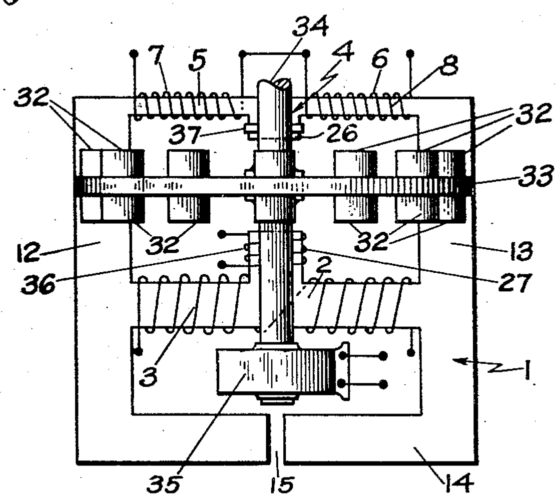

FIG. 10.

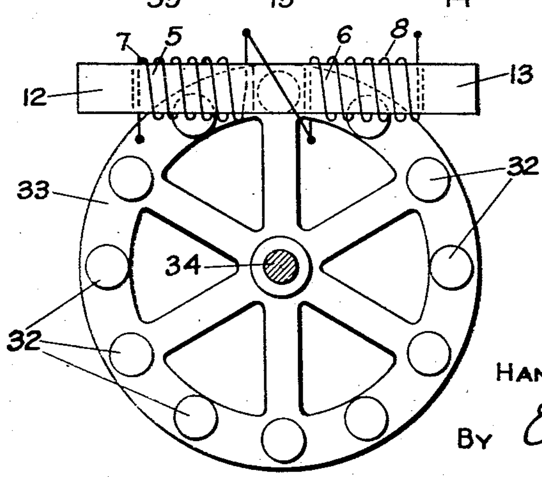

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FIG. 11.

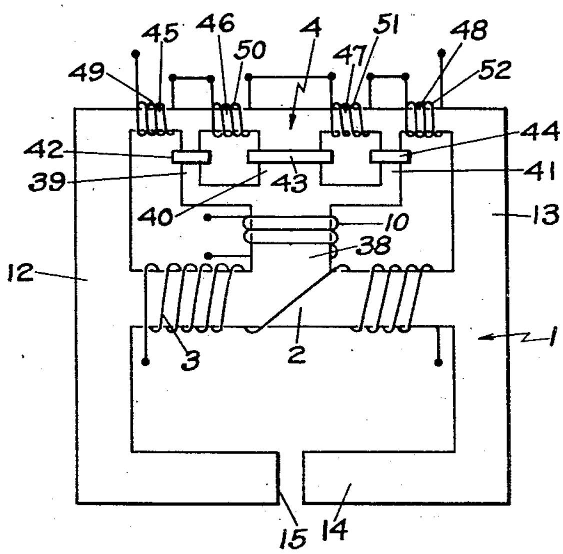


FIG. 12.

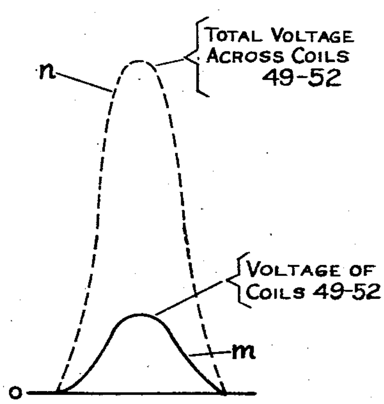


FIG. 13.

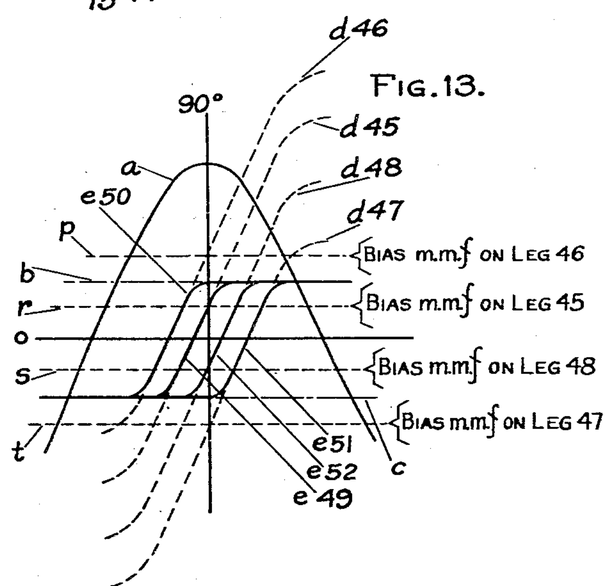
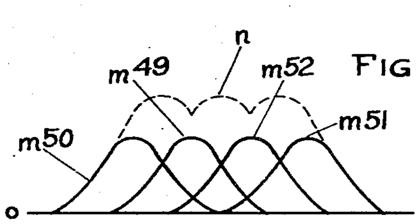


FIG. 13a.



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UNITED STATES PATENT OFFICE

2,466,028

CONTROLLED PEAKING TRANSFORMER

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Original application August 2, 1940, Serial No. 349,785. Divided and this application May 8, 1945, Serial No. 592,646

3 Claims. (Cl. 323—56)

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This is a division of applicant's copending application, Serial No. 349,785, filed August 2, 1940, now Patent No. 2,395,881, dated March 5, 1946.

This invention relates to controlled peaking transformers in which alternating voltages of sine wave form are converted into peaked waves of controllable magnitude. Heretofore, the control of the magnitude of the peaking output waves of such transformers has required a considerable amount of control power.

An object of this invention is to produce a peaking transformer in which the magnitude of the peaked output voltage may be varied through a wide range in response to a relatively small controlling factor.

Another object of this invention is to produce such variation by using small direct currents.

A still further object of this invention is to produce such variation by the use of movable magnetic means.

The foregoing and other objects of this invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein:

Fig. 1 is a diagrammatic representation of a peaking transformer embodying my invention;

Figs. 2, 2*a*, 3, 3*a* and 4 are curves representing the mode of operation of the arrangement shown in Fig. 1;

Fig. 5 is a diagrammatic representation of a modification of the arrangement shown in Fig. 1;

Figs. 6, 6*a*, and 6*b* are curves representing the mode of operation of the arrangement shown in Fig. 5;

Fig. 7 is a diagrammatic representation of a circuit in which the embodiment illustrated in Fig. 1 may be used;

Fig. 8 is a representation of a modified form of my invention using a movable magnetic control means;

Fig. 9 represents another embodiment of my invention in which motor driven movable magnet control means are utilized;

Fig. 10 is a top view of the device shown in Fig. 9;

Fig. 11 is a representation of a still further embodiment of my invention; and

Figs. 12, 13, and 13*a* are curves illustrating the mode of operation of the embodiment shown in Fig. 11.

The embodiment shown in Fig. 1 consists of a core member **1** made of suitable magnetic material such as iron. Said core is provided with a central leg **2** upon which the input winding **3** is

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wound. The winding **3** is adapted to be energized from some suitable source of alternating current usually of substantially sine wave form. On one side of the central leg **2** is located a saturable leg **4** preferably made of a material of high magnetic permeability such as permalloy steel. The saturable leg **4** is made with two side leg portions **5** and **6** upon which output coils **7** and **8** respectively are wound. The peaked output voltages are generated in these coils **7** and **8**, which, in the arrangement shown in Fig. 1, are connected in series. In order to introduce saturating flux, a leg **9** is provided extending from between the leg portions **5** and **6** to the central portion of the central leg **2**. A coil **10** is wound upon the leg **9** and is adapted to be supplied with direct current for the purpose of introducing sufficient direct current flux into the leg portions **5** and **6** to saturate them. The leg **9** is also preferably surrounded by a short-circuited loop **11** which tends to keep alternating flux out of the leg **9**. A pair of side legs **12** and **13** connect the outer ends of the leg portions **5** and **6** to the outer ends of the central leg **2** and extend beyond said central leg to a lower leg **14** which is adapted to carry the alternating current leakage flux. The lower leg **14** is provided with an air gap **15** which introduces magnetic resistance into the magnetic circuit of which the leg **14** is a part, and also serves to prevent the leg **14** from becoming saturated.

The operation of such an arrangement as is shown in Fig. 1 may be understood more clearly by referring to the curves in Figs. 2, 2*a*, 3, 3*a*, and 4. In these figures, *a* represents the voltage applied to the exciting or input coil **3**; *b* and *c* represent the positive and negative values of flux at which the leg **4** and its side leg portions **5** and **6** become saturated. Figs. 2 and 2*a* represent the operation without any appreciable direct currents supplied to the coil **10**. Under these conditions, the magnetomotive force applied to the leg **4**, represented by *d* varies about the zero flux axis and lags the voltage *a* by substantially 90 degrees. Since the flux in the legs **5** and **6** changes only as the magnetomotive force *d* causes said flux to pass between the two saturating values, voltages are generated in the coils **7** and **8** only during this period. Furthermore, the voltages which are generated in these coils are in phase. Therefore, in Fig. 2*a* the voltage which is generated in each of the coils **7** and **8** is represented by *h* and since these two coils are in series, the total output voltage across these coils may be represented by *i* which is double *h*. If the coil **10** is supplied with sufficient direct current to impress upon the leg 5 a bias magnetomotive force represented by f in Fig. 3 and to impress a bias magnetomotive force on leg 6 as represented by g in Fig. 3, the total output voltage i is substantially decreased as represented in Fig. 3a. Under these conditions, the alternating magnetomotive force $d5$ which is applied by the coil 3 to the leg 5 varies about the bias f as an axis and lags the voltage a by substantially 90 degrees as before. The alternating magnetomotive force $d6$ applied to the leg 6 by the coil 3 varies about the bias g as an axis and likewise lags the voltage a by substantially 90 degrees. Under these conditions, the flux $e7$ of the leg 5 which passes through the coil 7 is advanced in phase and the flux $e8$ of the leg 6 which passes through the coil 8 is delayed in phase. Therefore, as shown in Fig. 3a, the voltages $h7$ and $h8$ generated in the coils 7 and 8 respectively are no longer in phase but are delayed and advanced respectively to the same degree as the fluxes which generate them. Therefore the total output voltage i which still is the sum of the voltages of the coils 7 and 8 is reduced considerably in amplitude, with a somewhat increased width. However, in most applications to which such peaking transformers are put, the amplitude of the peaked output wave is the significant or controlling factor and therefore the widening of the voltage peak is non-objectionable.

It will be seen from the foregoing that by properly selecting the constants of the system, a relatively small value of direct current supplied to the coil 10 will vary the magnitude of the peaked output voltage wave to a comparatively great degree. For example, the controlling characteristics of such a system may be represented in Fig. 4 in which milliamperes of direct current bias supplied to the coil 10 may be plotted along the horizontal axis and the peak output voltage in kilovolts may be plotted along the vertical axis. The resultant variations may be represented by the curve k in Fig. 4. Of course, it is to be understood that the comparative values as represented in Fig. 4 may be varied over very wide limits by properly selecting the constants of the system as shown in Fig. 1.

Instead of connecting the coils 7 and 8 so that their voltages add, these coils can be connected so that their voltages oppose each other as represented in Fig. 5. In such an arrangement, when no direct current is supplied to the coil 10, the voltages of the coils 7 and 8 are equal and opposite, and the output voltage has zero amplitude. When the coil 10 is supplied with direct current, the separation as represented in Figs. 6, 6a, and 6b ensues. In these figures, the reference numerals have the same significance as in Figs. 2–4. As previously explained, the voltages $h7$ and $h8$ are no longer in phase with each other, but are displaced to a degree which by proper design may be that as represented in Fig. 6a. The output voltage from the coils 7 and 8 under these conditions consists of a succession of such peaked alternations as is represented in Fig. 6a. If it is desired to have each impulse uni-directional, a rectifying bridge 16 may be connected to the output of the coils 7 and 8 as represented in Fig. 5. Under these conditions, the two voltage peaks of the alternation represented in Fig. 6a are made uni-directional, giving the resulting output impulse as represented in Fig. 6b. Under these conditions, the voltage appearing at the output of the rectifying bridge 16 consists of a succession of such double peaked impulses as shown in Fig. 6b.

The peaked output voltage of this invention may be applied to any desired use. One of these uses is in connection with the control of an electrical space discharge tube. Such an application is represented in Fig. 7 in which electronic tube 17 is shown provided with an anode 18 and a cathode 19, preferably of thermionic type. The tube is provided with a control grid 20 which permits a discharge to start between the cathode and anode, when the grid is supplied with a starting voltage impulse. The tube is adapted to be supplied with alternating current from a pair of terminals 21 and 23. The terminal 21 is connected through a load 22 to the anode 18. The terminal 23 is connected directly to the cathode 19. The peaked output voltage of the coils 7 and 8 is connected between the cathode 19 and the grid 20. It is usually desirable in such instances to control the phase at which the igniting impulse is supplied to the igniting electrode. For this reason, a controllable phase shift device 24 of any suitable type is energized from the terminals 21 and 23 and has its output connected to the energizing coil 3 of the peaking transformer. As previously indicated, the amount of direct current power necessary for controlling the output of such a peaking transformer is relatively slight, and may be supplied in the arrangement shown in Fig. 7 from a thermocouple 25. The device 25, in some instances, may consist of a photo-electric cell or any other desired source of direct current.

The system illustrated in Fig. 7 operates as described in Fig. 1 so as to supply peaked voltages to the grid 20. In absence of energization of the coil 10 from the thermocouple 25, the amplitude of the peak voltage thus supplied is sufficient to initiate the discharge during each conducting half cycle of the alternating voltage applied to the tube 17. The point at which this firing voltage impulse is supplied to the electrode 20 is determined by the setting of the phase shift device 24. If, however, the thermocouple 25 is heated so as to operate the coil 10 with direct current, the output voltage of the coils 7 and 8 is reduced to such an extent that it is no longer sufficient in magnitude to ignite the tube 17 and thus the tube stops conducting current. It will be seen, therefore, that the tube 17 which may deliver large amounts of power to the load 22 can be energized and de-energized at will by the relatively small amount of energy delivered from the thermocouple 25.

Instead of utilizing direct current for supplying the saturating magnetomotive force, such saturating magnetomotive force can be supplied and controlled in other ways. For example, a movable magnet may be utilized for this purpose as illustrated in Fig. 8. In this figure, where the elements are identical with those shown in Fig. 1, the same reference numerals are applied thereto. In Fig. 8 the central leg of Fig. 1 is replaced by a pair of pole pieces 26 and 27 between which an armature 28 is rotatably mounted. The armature is made in the form of a permanent magnet although, if desired, it could be in the form of an electromagnet. A short circuited turn 29 corresponding to the short circuited turn 11 of Fig. 1 is provided on one of the pole pieces. The armature 28 is mounted upon a rotatable shaft 30 provided with some suitable means for rotating it such as a crank 31.

The operation of the arrangement shown in Fig. 8 is identical with that described in connection with Figs. 1–4. However, in connection with Fig. 8, the magnetomotive force which is supplied as a bias to the legs 5 and 6 varies with the angular relationship between the pole pieces 26 and 27 and the armature 28. Thus the operation of the device shown in Fig. 8 with the armature 28 in line with the pole pieces can be represented by Figs. 3 and 3*a* in which a reduction in the amplitude of the output voltage is secured. The operation with the armature 28 substantially at right angles to the pole pieces 26 and 27 can be represented by Figs. 2 and 2*a* in which an increase in the amplitude of the output voltage is secured. Fig. 4 can represent the operating characteristics of the arrangement shown in Fig. 8 if the angular displacement from vertical position of the magnetic armature 28 is plotted along the horizontal axis.

Instead of utilizing a single movable magnet, as shown in Fig. 8, a plurality of movable magnets can be utilized as illustrated in Figs. 9 and 10. Here likewise, where elements are identical with those in Fig. 1, the same reference numerals are applied. In Figs. 9 and 10, the single movable magnet of Fig. 8 is replaced by a plurality of magnets 32 mounted on a wheel 33 which is rotatably supported on a shaft 34. The shaft may be rotated by any suitable means which preferably consists of a synchronous motor 35.

If the arrangement shown in Figs. 9 and 10 is applied, for example, to a system as shown in Fig. 7, the synchronous motor 35 can be driven from the same source of alternating current as that which energizes the coil 3. Under these conditions, the constants of the system and the number of magnets 32 can be so selected that, during each cycle, one of the magnets 32 passes between the pole pieces 26 and 27. These can be so adjusted that they are in alignment during each conducting half cycle applied to the tube 17. Under these conditions, the amplitude of the output voltage of the coils 7 and 8 is maintained at a reduced value so that the tube 17 does not fire. In order to cause the tube 17 to fire, the magnets 32 are made removable. Therefore, as one of the magnets 32 is removed, the tube 17 will fire and conduct current during the cycle corresponding to the removed magnet. By properly selecting magnets 32 for removal, any desired sequence of operation of the tube 17 or any other device controlled by the coils 7 and 8 may be produced.

If, instead of having the voltage of the coils 7 and 8 add, the arrangement of these coils as represented in Fig. 5 is utilized, the opposite effect is produced, namely the tube 17 fires whenever one of the magnets 32 is in alignment with its associated pole pieces and the tube is prevented from firing merely by removing one or more of the magnets 32.

In some cases, it may not be desirable to have each of the elements 32 in itself a permanent magnet, but rather a magnetic armature member. Under these conditions a D. C. exciting coil 36 can be mounted on one of the pole pieces 27 and the usual short circuited loop 37 may be mounted on the other pole piece 26. The operation under these conditions will be exactly the same as if the members 32 were themselves permanent magnets. A similar variation could be introduced into Fig. 8.

Another mode of operation of the arrangement shown in Fig. 9 could be to have the coil 36 excited with a sufficient magnitude of current to produce an initial saturation of the legs 5 and 6 so as to produce an initial phase displacement between the voltages of coils 7 and 8. If, under these conditions, the members 32 are in the form of permanent magnets polarized so as to oppose the magnetization of the coil 36, each of the magnets 32 as it comes into alignment with the poles 26 and 27 will cancel the magnetomotive force of the coil 36 and eliminate the initial phase displacement between said voltages. Here, likewise, as each magnet 32 comes into alignment with the pole pieces 26 and 27, the amplitude of the output voltage across the coils 7 and 8 will be increased and as said magnet passes out of such alignment the amplitude of the output voltage will be decreased.

The relative values of the maximum and minimum amplitudes of output voltage of peaking transformers constructed in accordance with my invention may be increased by utilizing somewhat more complex forms thereof. An arrangement of this kind is shown in Fig. 11. Here likewise, where elements are identical with those shown in Fig. 1, the same reference numerals are applied. In Fig. 11 the central direct current bias leg is replaced by a central leg 38 subdivided at its upper end into three smaller legs 39, 40, and 41. The legs 39, 40, and 41 may be provided with short circuited rings 42, 43, and 44 respectively. The saturable leg 4 is subdivided into four sections, 45, 46, 47 and 48 instead of the two sections of Fig. 1. In Fig. 11, the saturable leg sections 45—48 are provided with coils 49, 50, 51 and 52 respectively. The D. C. saturating coil 10 is placed upon the main leg 38.

The operation of the device shown in Fig. 11 may be best understood by referring to Figs. 12, 13, and 13*a*. Here likewise, the same reference letters are applied as in the case of Figs. 2 and 3*a*, where the curves are identical. In Fig. 12 m represents the voltage of one of the coils 49—52 without any appreciable direct currents supplied to the coil 10. Therefore, the total voltage n across all of the coils 49—52 is four times the value m. In Fig. 13 p, r, s, and t represent the bias magnetomotive forces on legs 46, 45, 48, and 47 respectively. Due to the fact that the resultant magnetomotive forces applied to the legs 45—48 respectively vary about the bias fluxes p—t as axes, the voltages generated in the coils 49—52 are displaced in phase with respect to each other as explained in connection with Fig. 1. This relative displacement between these voltages is represented in Fig. 13*a*. The summation of these displaced voltages is also represented in Fig. 13*a* by n. A comparison of the peak amplitude of the voltages of Figs. 12 and 13*a* shows that in the arrangement of Fig. 11 a greater change in the amplitude of the output voltage is obtainable by this arrangement than by the previously described embodiments.

Of course, it is to be understood that this invention is not limited to the particular details as described above, as many equivalents will suggest themselves to those skilled in the art. For example, instead of utilizing direct current for the saturating magnetomotive force, alternating currents of various kinds could be utilized in particular embodiments. Also, different features of each embodiment could be incorporated into each of the other embodiments. Various other applications of the principles enunciated herein could be utilized by persons skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A peaking transformer system comprising a

plurality of saturable core portions, a coil on each of said core portions connected in series with each other, movable magnetic means for impressing a variable magnetomotive force bias on each of said core portions, means for superimposing a periodically varying magnetomotive force on each of said core portions, the relation between said bias and varying magnetomotive forces being different in different core portions whereby voltages induced in said coils by said varying magnetomotive force are displaced in phase with respect to each other and means for continuously moving said movable magnetic means into and out of effective relation with respect to said saturable core portions in synchronism with said periodically varying magnetomotive force.

2. A peaking transformer system comprising a plurality of saturable core portions, a coil on each of said core portions connected in series with each other, a plurality of movable magnetic means for each impressing a variable magnetomotive force bias on each of said core portions, means for superimposing a periodically varying magnetomotive force on each of said core portions, the relation between said bias and varying magnetomotive forces being different in different core portions whereby voltages induced in said coils by said varying magnetomotive force are displaced in phase with respect to each other, and means for moving said movable magnetic means into and out of effective relation with respect to said saturable core portions in synchronism with said periodically varying magnetomotive force.

3. A peaking transformer system comprising a plurality of saturable core portions, a coil on each of said core portions connected in series with each other, a plurality of movable magnetic means for each impressing a variable magnetomotive force bias on each of said core portions, means for superimposing a periodically varying magnetomotive force on each of said core portions, the relation between said bias and varying magnetomotive forces being different in different core portions whereby voltages induced in said coils by said varying magnetomotive force are displaced in phase with respect to each other, and means for moving said movable magnetic means into and out of effective relation with respect to said saturable core portions in synchronism with said periodically varying magnetomotive force, each of said movable magnetic means being removable from operative relation with respect to said system whereby the control of the output voltage across said coils may be predetermined for each cycle of said periodically varying magnetomotive force.

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