Jan. 31, 1928. 1,657,574

L. A. HAZELTINE

METHOD AND APPARATUS FOR CONVERTING ELECTRIC POWER

Filed July 28, 1925 2 Sheets-Sheet 1

FIG. 1A

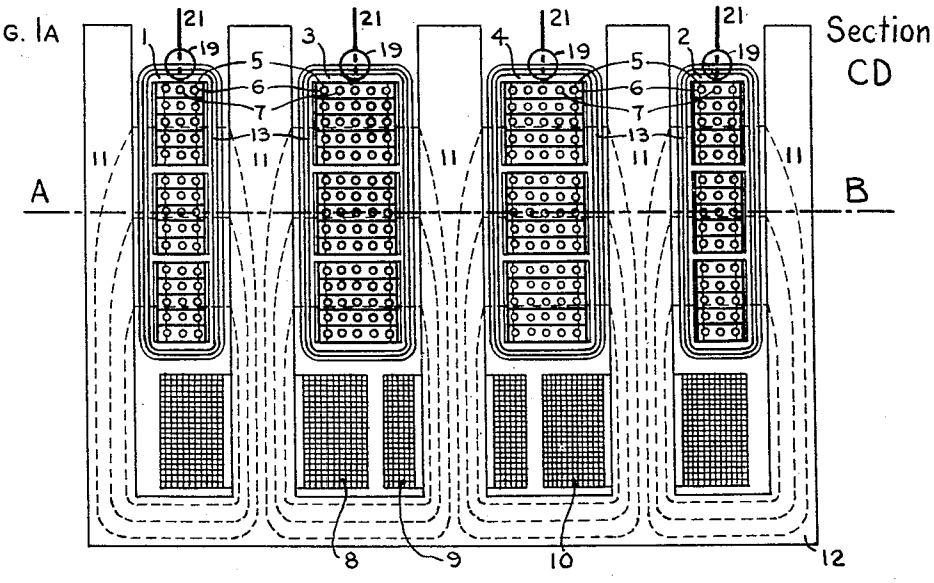
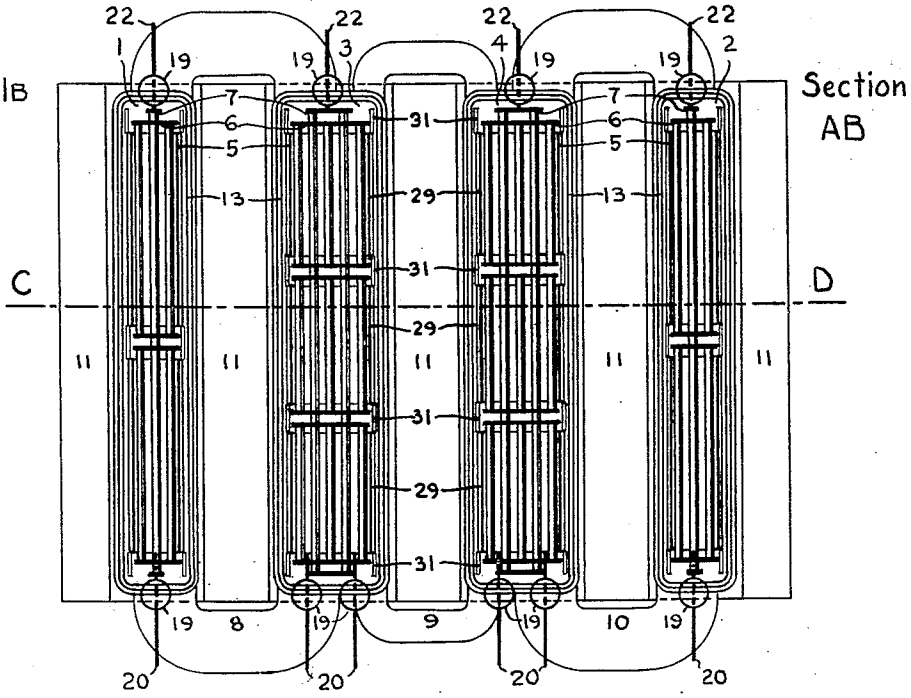


FIG. 1B



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Filed July 28, 1925 2 Sheets-Sheet 2

FIG. 2A

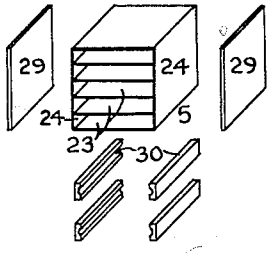


FIG. 2B

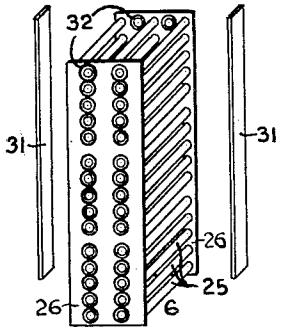


FIG. 2C

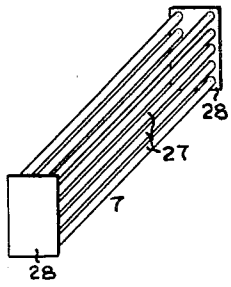


FIG. 3

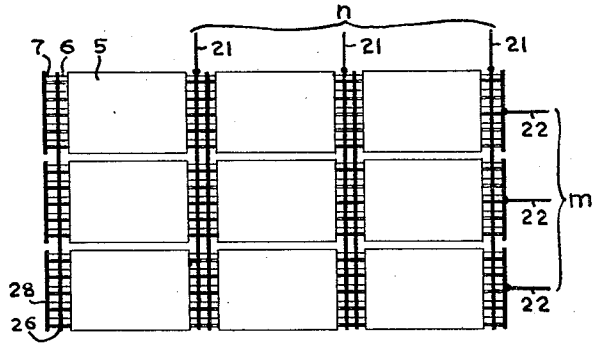
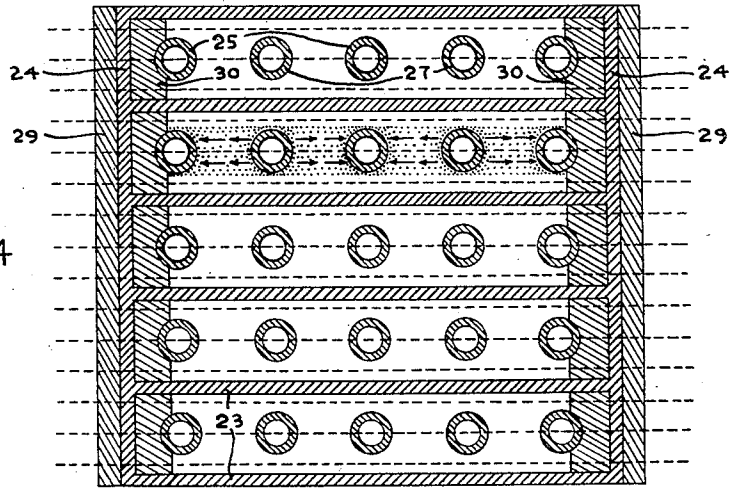


FIG. 4



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UNITED STATES PATENT OFFICE.

LOUIS A. HAZELTINE, OF HOBOKEN, NEW JERSEY.

METHOD AND APPARATUS FOR CONVERTING ELECTRIC POWER.

Application filed July 28, 1925. Serial No. 46,528.

This invention relates to an electrostatically controlled magnetically guided valve converter and constitutes an improvement over the form of valve converter described in my pending application for Letters Patent, Serial No. 649,536, filed July 5, 1923.

The principal object of this invention is to provide more certain and reliable means for preventing electronic currents from flowing in undesired paths and thereby causing losses.

A second object of this invention is to provide a valve structure which is mechanically strong and rigid, with a minimum of external supports and of electrical connectors.

A third object of the invention is to provide a form of magnetic core which minimizes stray magnetic fields and which is of such open construction as to leave a maximum space for bringing out the leads from the valves.

In the valve converter whose structure is illustrated in Figs. 58[a] to 59 of my patent application above referred to, electron emission occurs from certain portions of the surfaces of the main electrodes, but not from the remaining portions nor from the surfaces of the control electrodes. Such selective emission is secured by coating portions of the main electrode surfaces with an electron-emissive material, such as calcium oxide, and employing for the remaining surfaces a highly non-emissive material, such as uncoated tungsten. Unless means are provided for maintaining differences in temperature, it may be difficult to prevent sublimation of the emissive coating from one portion of the surface to another, with consequent undesired emission. This difficulty is avoided in the present invention by arranging the electrode surfaces so as to eliminate all undesired electron paths between exposed portions of the surfaces, and by placing barriers in the paths that must exist for structural reasons between surfaces that do not need to be exposed. These ends are attained by arranging the electrodes so that, when their outlines are projected into a plane perpendicular to the magnetic flux, the projections of the exposed portions of the main electrodes will not overlap the projections of the exposed portions of the control electrodes, and by interposing barriers of insulating material in places where the projections of the remaining portions of the electrodes overlap. The result is that it is unnecessary to depend on selective emission from the different electrodes or portions thereof.

Referring to the drawings:

Fig. 1[a] shows an elevation in section of a valve converter arranged in accordance with this invention. Fig. 1[b] shows a plan in section corresponding to Fig. 1[a].

Figs. 2[a], 2[b] and 2[c] show oblique projections of the structures of the control electrodes, the low-frequency electrodes and the high-frequency electrodes, respectively.

Fig. 3 shows a side view of one valve structure with the containing vessel removed.

Fig. 4 shows a detail of the valve structure.

The valve converter illustrated in the accompanying drawings has the following features in common with that illustrated in Figs. 58[a] to 59 of my prior application above referred to. It has a number of separate valve structures (1, 2, 3 and 4) each placed between the poles (11) of an electromagnet (12) excited by direct current (in the coils 8, 9 and 10). Each valve structure consists of a highly evacuated vessel inside of which are reflectors consisting of concentric metal shells (13), preferably polished, for the purpose of retaining the heat developed by the losses in the valves and so maintaining the main electrodes at the proper temperature for electron emission. Within the reflectors are the valves proper, each consisting of a control electrode (5), and two main electrodes (6 and 7).

During a portion of each control cycle, the control electrode 5 is highly positive relative to the main electrodes and causes electrons to flow from one main electrode to the other as illustrated by the dots and arrows in Fig. 4. These electrons are drawn from whichever of the main electrodes 6 or 7 happens to be the cathode and are rapidly accelerated to high velocity. It is well known that in a magnetic field an electron initially moving obliquely to the lines of magnetic flux will describe a path of a helical character having a line of magnetic flux for an axis. If the magnetic field is intense, the path will at all points be so close to its axis that the latter may roughly represent the actual path. This effect has been

employed for guiding electrons in vacuum tubes so that they travel essentially along lines of magnetic flux. Thus in Fig. 4 the electrons are guided by the magnetic field, tending to move along the lines of magnetic flux (represented by dotted lines) and being prevented from reaching the surfaces of the control electrode which are out of the direct path. The electrons therefore continue their motion after they pass the point of maximum potential midway between the main electrodes, and are retarded so that they strike the anode with a low velocity. Some of the electrons which happen to have a slightly lower longitudinal velocity than the others will not quite reach the anode and will return towards the cathode, oscillating back and forth throughout the interval when the control electrode is positive. During the remaining portion of the control cycle the control electrode will be highly negative with respect to both main electrodes and will prevent the flow of electronic current. At the beginning of this interval all electrons present in the space will be drawn to the main electrodes.

The specific valve converter illustrated in the drawings may be associated with the circuits illustrated in Figs. 54, 56, 57[a] and 57[b] of my prior application above referred to, and therefore includes 12 direct-current valves and 18 alternating-current valves, each valve having a separate control electrode.

The valve converter illustrated herewith differs from that of my prior application in the following respects. First, the direct-current valve structure is made in two parts 1 and 2, and the alternating-current valve structure is also made in two parts, 3 and 4. Secondly, the individual valves of each valve structure, instead of being placed side by side in the direction of the magnetic flux lines, are placed in the same plane perpendicular to the magnetic flux and in a rectangular arrangement (as illustrated in Fig. 3) with as many valves in one direction as there are output leads 21 from that structure and as many valves in the other direction as there are input leads 22, with the result that input and output electrodes may each be made common to several valves. Thirdly, the active portions of the main electrodes consist of parallel tubes (or rods or strips) 25 and 27 displaced from one another in the direction of the magnetic flux lines; and the active portion of the control electrode consists of plates 23 parallel to the magnetic flux lines and to the main electrodes. The active portions of each electrode are firmly held in position by metal end plates 24, 26, 28. Around these end plates are interposed barriers 29, 30, 31 of insulating material to prevent the flow of electrons.

The splitting of the direct-current valve structure and the alternating-current valve structure into two parts has several advantages. First, it brings all of the large exposed iron surfaces (at each side and at the bottom of Fig. 1[a]) to the same magnetic potential, thus minimizing the tendency for magnetic flux to pass to an enclosing tank. Secondly, it leaves the top and both ends of each valve structure exposed for bringing out leads. Most conveniently the control leads 20 are brought out at the front of Fig. 1[a], the high-frequency leads 22 at the rear, and the direct-current and low-frequency leads 21 at the top. Thirdly, the number of leads to be brought out from one vessel is much less ($2+3+6=11$, as against $2+6+12=20$, for the direct-current valves, and $3+3+9=15$, as against $3+6+18=27$, for the alternating-current valves), with only a slight increase in the total number of leads to be brought out ($11\times2=22$, as against 20, for the direct-current valves and $15\times2=30$, as against 27, for the alternating-current valves), thus simplifying the arrangement of the insulating seals 19. Fourthly, the smaller number of valves results in a more rigid and stronger mechanical structure. Fifthly, the three dimensions of the complete structure are not far from equal, making the arrangement more compact.

This structure is particularly suitable for large power ratings, such as several hundred kilowatts. For smaller power ratings it might be preferable to use a smaller number of valve structures, even going as far as putting all valves in a single structure, associated with a single magnetic field.

The arrangement of all of the valves of each valve structure in a single plane, as described above, avoids all special connectors between main electrodes in any circuit-closing valve converter connected in accordance with the scheme of Fig. 37 of my prior application above referred to. For example, referring to an alternating-current valve structure having m high-frequency electrodes and n low-frequency electrodes giving mn valves altogether, each with a separate control electrode, m valves may be placed one above the other and n valves end to end, in a rectangular arrangement, as shown in Fig. 3. The m valves one above the other may have the tubes 25 forming the low-frequency electrodes connected between two parallel metal plates 26, as shown in Fig. 2[b], making a very rigid structure which is the primary support for the remaining electrodes. The n valves associated with one high-frequency electrode may be placed end to end, the high-frequency electrodes consisting of tubes 27 extending through all of these valves, as illustrated in Fig. 2[c]. These tubes will pass through insulating bushings 32 in the end plates 26 of the low-frequency electrodes, as shown in Fig. 2[b], which serve as

mechanical supports. The control electrodes are fixed relative to the low-frequency electrodes by the insulating pieces 30, which serve also as barriers to electron flow between the end plates 24 of the control electrode and the main electrodes.

Insulating barriers 29 are placed over the end plates 24 of the control electrodes to prevent electrons from being emitted by these end plates. For the same purpose insulating barriers 31 are placed at each side of the exposed end connections of each valve, as shown in Fig. 1b. In general, such insulating barriers should be interposed wherever magnetic flux lines extend from one conducting surface to another, one of which is emissive.

The motion of the electrons between the main electrodes has a component parallel to the electrodes, which may be referred to as a drift, and which carries the electrons perpendicularly to both the magnetic flux lines and the dielectric flux lines. When this drift carries the electrons to the end of the active space of a valve, the electrons will curve around the edges of the control electrode, still moving perpendicularly to the dielectric flux lines. The result is that any electron which is oscillating back and forth between the main electrodes without reaching them will experience a drift that will carry it completely around one of the plates of the control electrode. No barrier should be interposed in the path, as such a barrier would accumulate a negative electric charge from the electrons and would impair the action of the valve.

When the control electrodes are negative a cloud of electrons will form over their surfaces. The electrons in this cloud will also experience a similar drift to that described above, which for the same reason should not be interrupted by barriers. The clearances around the surfaces of the control electrodes are chosen with respect to the voltages and to the strength of the magnetic field so that this electron cloud does not extend to the main electrodes nor to the other control electrodes.

During motion from one main electrode to another, the electrons are subjected by the control electrode to a varying transverse force. In general electrons moving in a magnetic field have a certain natural period of rotary motion. If this period of rotary motion should happen to lie close to the time taken by an electron to traverse the space between the main electrodes, then those electrons which are oscillating back and forth between electrodes may build up relatively high transverse velocities, which ultimately may carry them to the surface of the control electrode. The same will be true, but to a less degree, if the natural period of rotation corresponds to some harmonic component of the transverse force. This effect is obviated by the cooperation of two means: first, the transverse force is made as uniform as possible, particularly avoiding harmonic components; and secondly, the strength of magnetic field is so chosen that the time taken by electrons to traverse the space between electrodes and its submultiples are removed as far as possible from the natural period of rotation of the electrons. The second means is most conveniently determined by trial by adjusting the magnetic field for a minimum current in the control electrode circuit. The first, means is accomplished by suitably shaping the surfaces of the electrodes. The use of round main electrodes with plane control electrodes gives a comparatively uniform transverse field and it is preferred to the use of flat strips. The round electrodes also are simpler structurally and provide a greater emissive surface than would flat strips.

I claim:

1. An electrostatically controlled valve comprising an evacuated vessel, two main electrodes and a control electrode, and means for maintaining a constant magnetic flux for guiding the electrons between said main electrodes, the lines of said magnetic flux extending from one main electrode to the other main electrodes, and the projections of the control electrode not overlapping the projections of the main electrodes when the outlines of the exposed portions of the electrodes are projected on a plane perpendicular to the lines of magnetic flux.

2. An electrostatically controlled valve comprising an exacuated vessel, two main electrodes therein whose active surfaces have the form of parallel cylinders, a control electrode whose active portion has the form of plates parallel to the plane including the axes of said main electrodes, means to maintain a constant magnetic field passing through the valve in the plane including the axes of the main electrodes and perpendicular to said axes, and insulating barriers interposed in all paths where inactive metallic surfaces would otherwise face one another along lines of magnetic flux, whereby no electron paths along lines of magnetic flux exist between electrodes except the desired paths between the active surfaces of said main electrons.

3. In a magnetically guided electrostatically controlled valve converter having a certain number m input leads, a certain number n output leads, and mn valves arranged to connect each input lead with each output lead, the rectangular arrangement of the mn valves in a single plane perpendicular to the magnetic flux, with m valves in one direction and n valves in the other, and with the input and output electrodes each

structurally common to a number of valves, whereby the required number of electrical connectors and mechanical supports for said valves is minimized.

4. In a magnetically guided electrostatically controlled valve converter, the combination of a magnetic core having an odd number of poles symmetrically arranged and proceeding from a common yoke, exciting coils wound on said poles except the two end poles whereby external magnetic fields are minimized, and a symmetrical arrangement of valve structures placed between said poles, with the result that three sides of each valve structure are available for bringing out leads.

5. A magnetically guided electrostatically controlled valve as claimed in claim 2, which includes free paths around the ends of the plates of the control electrodes, along which paths electrons drift perpendicularly to the magnetic flux and to the dielectric flux existing between electrodes thereof.

6. In an electrostatically controlled valve converter, the method of minimizing the current to the control electrode which consists in employing a magnetic field to guide the motion of electrons and in so adjusting the strength of said magnetic field that the natural period of rotary motion of the electrons passing between the main electrodes does not equal or approximate the time taken by an electron in traveling from one main electrode to another, nor a submultiple of this time.

In testimony whereof I affix my signature.

LOUIS A. HAZELTINE.

CERTIFICATE OF CORRECTION.

Patent No. 1,657,574. Granted January 31, 1928, to

LOUIS A. HAZELTINE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 15, after the word "one" insert the word "inactive"; same page, line 104, claim 2, for the misspelled word "exacuated" read "evacuated", and line 120, last word of claim, for "electrons" read "electrodes"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of February, A. D. 1928.

Seal.

M. J. Moore,
Acting Commissioner of Patents.

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Seal.