This invention relates to electron discharge devices, more particularly to improvements in magnetically biased electron discharge devices in which the electron discharge is influenced by a magnetic field.

The conventional magnetically biased electron discharge device comprises three different components, that is, an electron discharge device, a means for creating a magnetic field, and the circuit elements and voltage sources associated with the device. The dimensions of the electron system of the electron discharge tube, among other things, are governed by the wavelength to be generated, and they must be smaller, the shorter the desired wave-length. The efficiency of device is comparatively low when operated at ultra high frequencies, an efficiency of about 10 per cent being considered quite favorable where waves of 50 centimeters or less are dealt with. The result at these frequencies is that thermal losses are developed in the electrode system which are several times greater than the useful energy which results. Inasmuch as the electrodes for the production of ultrashort waves must be of very small dimensions, they will be capable of handling only a relatively small load and are able to deliver only a small output of oscillating energy. Hence, whenever more than the average power output is required, it is necessary to connect in parallel a plurality of the magnetically biased electron discharge devices.

Serious difficulty with the usual parallel connection, however, is that the length of the wires connecting the various tubes is approximately the same as the length of the wave to be generated. Hence, these connecting wires must be tuned to whatever wave-length is being generated in order that they may not offer an unduly great resistance to the flow of radio-frequency energy and in order that during operation proper cooperation may be had between the various tubes by having a proper current and voltage phase relation between the tubes. However, the necessity of such tuning makes it harder not only to adjust the parallel arrangement when operating on a given wave-length, but makes it especially difficult to obtain a change in wavelength or frequency. There are also a number of other difficulties which make the use of the usual parallel connections impractical. The prior practice has usually been to combine two or more sets or units each comprising an electron discharge tube and the means for producing the requisite magnetic field. When the magnetic field is generated by the aid of an electromagnet, the inherently high consumption of energizing energy of the electron discharge device when operated at ultra high frequencies increased many times. In the case of permanent magnets for which the weight per unit can be estimated at a little over two pounds, a parallel arrangement leads to such an increase in the weight and the volume of the arrangement that it can no longer be seriously considered for most practical cases. Another difficulty is that not only the electrical, but also the magnetic data of the various units have to be matched; and the necessity of the additional adjustments means a considerable handicap in the use of magnetically biased electron discharge tube arrangements compared with other ways and means of generating very high frequencies such as the retarding-field type of circuit arrangement of Barkhausen-Kurz.

The object of our invention is to provide an improved magnetically biased electron discharge device which not only has a comparatively high power output but is simple in construction and easy to adjust and operate over a wide range of ultra high frequencies.

According to our invention, two or more electron discharge devices are disposed in the same magnetic field and operated simultaneously. For the purpose of minimizing space requirements and reducing the air-gap to be traversed by the lines of force of the magnetic field, all electron discharge devices are preferably accommodated inside one evacuated envelope. In order that the connecting leads and wires between parallel electrode assemblies may be made as short as possible or may be dispensed with entirely, the anodes of the various electrode assemblies are structurally combined.

By the use of a joint magnetic field for all the units the use and operation of the apparatus is substantially simplified. The accommodation inside a single vessel of the various electrode assemblies is conducive to a compact assembly for which the requisite magnetic field will not be substantially larger than that required for a single electron discharge device. If the discharge anodes of the various constituent systems are directly inter-connected, the combination will be independent of any frequency adjustment, which is necessary where connecting wires are used, and will thus be just as simple in manipulation as a single tube.

The novel features which we believe to be characteristic of our invention are set forth with par-
ticularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings in which Figure 1 is a view in elevation of a magnetically biased electron discharge device made according to our invention, Figure 2 is a section transverse to the longitudinal axis of a modification of our invention, and Figure 3 is a view partly in section of a still further modification of the invention. Figure 4 is an enlarged longitudinal section of a portion of Figure 3 showing details of construction, Figure 5 shows a plurality of magnetrons such as shown in Figure 3 connected in parallel for increased output, Figure 6 is a diagrammatic showing in perspective another modification of our invention, and Figure 7 is a section transverse to the longitudinal axis of a still further modification of our invention.

In the modification shown in Figure 1, a permanent magnet M consisting of a material possessing a high coercive force, that is a material which maintains its magnetism very well, is used for providing a magnetic field. In the air-gap between the two poles P are mounted two electron discharge devices R, each of which has a straight cathode K and a single or multiple anode A. The circuit elements associated with the tube have been omitted in the drawing inasmuch as they are immaterial so far as the basic idea of this invention is concerned. The two tubes may be operated in a push-pull circuit or in a parallel circuit. In order that the magnetic field may be concentrated inside the smallest possible space the tubes R are disposed so that the electrode assembly comes as close as possible to the glass wall of the envelope, so that the distance between the two systems will be very small and so that the air-gap between the poles P will be small.

Both of the electrode systems could of course be accommodated within a single evacuated envelope, in which case the electrode systems could be placed still more closely together. The series connection of the cathode filaments can be used inasmuch as the fall of heating voltage along the relatively high plate potential, which for very short wave lengths may be of the order of magnitude of 1000 volts. A series connection, especially for direct supply line operation, offers the advantage that the excess voltage to be dissipated in the case of direct current supply will be lower, while for alternating current supply conditions, the requirements of the heating-current transformer are more favorable.

In another modification of our invention it has been especially satisfactory in combining a plurality of magnetically biased electron discharge devices, all of the anodes of the separate electrode assemblies having been structurally combined. In Figure 2, which is a cross-section transverse to a longitudinal axis, the envelope of the electron discharge device contains six paralleled discharge paths, each one of which includes a thoriated cathode K' and a pair of anodes A1, A2. The anodes are combined into six groups to form two closed surfaces which are parallel to and surround the cathodes, while the cross-sections of each group of anodes form roughly a plurality of joined semi-circles. It will be seen that in this embodiment all connecting leads are dispensed with between the paralleled anode halves so that the arrangement entirely eliminates any difficulties which arise when the connecting leads have to be tuned as in the conventional parallel arrangements. The filaments, for example, may be connected in series so that only two connections or terminals for the heating circuit are needed. Furthermore, only one terminal is required for each anode group. The six inner anode halves A2 form a tubular hollow space, which may be utilized for a number of purposes. For example, the cathode filament leads could be brought thru this space, and this, as will be readily seen, would insure perfect shielding for the filament leads. The inner anode could be employed also for the conduction thru the device of a cooling medium, for example, water or cool air. An electro-magnetic coil (not shown) surrounds the envelope G.

Inasmuch as the outer anode halves A1 form a closed surface, the latter could be used to form the wall of the envelope. This simplifies construction and promotes the dissipation of heat. The mounting of the systems as shown in Figure 2 offers an opportunity for a particularly favorable construction and formation of the power carrying connection to be connected with the two plate groups.

In Figure 3 is shown a multiple-unit magnetically biased electron discharge device in conjunction with concentric lines or leads which can be used as a circuit or as transmission lines. The outer connected anode halves A1' form the lateral walls of the vacuum vessel which is closed at both ends by insulating disk-shaped members B on which the inner electrodes are supported. The cathode filament current lead-ins H are mounted in one of the disks B. The outer anodes A1' terminate in a metallic tube E1, and the inner anodes A2' (see Figure 4) terminate in a metallic tube E2. These two concentric tubes so combined provide a transmission line adapted to carry radio frequency oscillations to the useful circuit, i.e., the aerial and also for conducting the direct current supply for the anodes. The magnetic field is set up by a co-axial coil F. Ceramic materials have been found to be particularly suitable for the construction of the concentric lines. Vacuum tight connections between the anodes, the filament-current leads and the ceramic disks are provided by means of intermediate layers of glass.

Figure 4 is an enlarged longitudinal section of the modification shown in Figure 3, the illustration being schematic in nature. The two anode systems again are denoted by A1' and A2', their extensions E1 and E2 constituting the concentric lines. The cathodes K' are supported by the end disks B and can be connected in series. The electrodes are sealed in the disk B of organic material by the intermediate layers or coating of glass Z. The inner anode group may be extended to the left in the shape of a tube. Inside the latter is a concentric tube W1, W2. This tube-system serves for the intake and exhaust conduits of a cooling medium or refrigerant which flows along the path designated by the arrows. The tube W serves for the generation of the magnetic field.

In case a still larger power output is desired than that possible with one multi unit arrangement, the construction as fundamentally outlined in Figures 3 and 4 can be modified to provide several such multi unit arrangements in parallel in a very practical and satisfactory manner.
Referring to Figure 5, the outer anode systems of two multi unit arrangements T1 and T2 are inter-connected by means of the concentric energy-feed systems E3, E4, such as described above, this system being extended to one side, additional tubes to the number desired being so added by other concentric lines E5, E6 for each anode, the last being connected to the load. The cathodes of these tubes are connected in series and to the leads H to which the filament current is fed. The magnetic field is set up separately for each tube by the aid of the field coils F.

Another disposition of a plurality of electron discharge systems in a single envelope is indicated schematically and in perspective in Figure 6. Four discharge systems are provided and each of these consists of a rectilinear cathode K1 and two semi-cylindrical anodes A3, A4. The electrode systems are disposed in parallel relation to each other in such a fashion that their heated cathodes are positioned in one and the same plane, while the anodes are united to form two corrugated-sheet structures. This arrangement is placed within an evacuated envelope and an electro-magnetic coil (not shown) placed around the entire system. This method of mounting results in very simple electrode shapes and supports. The arrangement as shown in Figure 6 is especially suited for a limited number of discharge systems, while the scheme shown in Figure 2 is especially suited for a much larger number.

A particularly simple modification of our invention is made possible by the use of molded pieces of ceramic body having on their surfaces metallic coatings or deposits which serve as the anodes. The ceramic body serves preferably at the discharge systems as the envelope of the tube. As shown in Figure 7, which is a section transverse to the longitudinal axis J1 and J2 are two bodies of ceramic material disposed one within the other and having adjacent surfaces provided with oppositely disposed semi-cylindrical depots, the thermionic cathodes K2 lying along the axis of the resulting tubular chambers. The adjacent surfaces of the ceramic bodies are provided with metallic coats or linings A5 and A6, and these may be made by spattering or spraying, and may serve as anodes. The central bore C may be used for conducting a cooling fluid throu it. An electro-magnetic coil (not shown) surrounds the outer ceramic body. The employment of ceramic material is particularly suitable in the case of multi unit arrangements as much as it is easy to exactly shape the material so that the different discharge systems are alike. The problem of mounting, which is ordinarily serious in multi unit arrangements is by means of this modification simply solved.

While we have indicated the preferred embodiment of our invention of which we are now aware and have also indicated only one specific application for which our invention may be employed, it will be apparent that our invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in this particular structure used and the purpose for which it is employed without departing from the scope of our invention as set forth in the appended claims.

What we claim is:

1. A magnetically biased electron discharge device including, means for generating a magnetic field, a plurality of electron discharge systems positioned within the magnetic field, the outer anode systems of two multi unit arrangements T1 and T2 being exterior of said circle of cathodes and providing a plurality of straight thermionic cathodes mounted parallel to each other in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, said anodes being disposed symmetrically with reference to each other and the cathodes, and providing semi-cylindrical surfaces oppositely disposed and coextensive with and surrounding said cathodes.

2. A magnetically biased electron discharge device including, means for generating a magnetic field, a plurality of electron discharge systems positioned within the magnetic field and including a plurality of straight thermionic cathodes mounted parallel to each other in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, said anodes being exterior of said circle of cathodes and providing semi-cylindrical surfaces oppositely disposed and coextensive with and surrounding said cathodes.

3. A magnetically biased electron discharge device including, means for generating a magnetic field, a plurality of electron discharge systems mounted in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, one set of anodes being positioned on one side of said cathodes and the other set of said anodes being positioned on the other side of said cathodes, each set of anodes being formed of a single sheet of metal and providing with the other set of anodes oppositely disposed semi-cylindrical surfaces coextensive with and surrounding said cathodes.

4. A magnetically biased electron discharge device including, means for generating a magnetic field, a plurality of electron discharge systems positioned within the magnetic field and including a plurality of straight thermionic cathodes mounted in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, one set of anodes being positioned on one side of said cathodes and the other set of said anodes being positioned on the other side of said cathodes, the anodes of each set being electrically connected together, each set of anodes providing with the other set of anodes oppositely disposed semi-cylindrical surfaces coextensive with and surrounding said cathodes.

5. A magnetically biased electron discharge device including a plurality of straight round thermionic cathodes of small diameter mounted in spaced relation parallel and coextensive with each other, two sets of anodes cooperating with said cathodes, one set of anodes being positioned on one side of said cathodes and the other set of said anodes being positioned on the other side of said cathodes, the anodes of each set being electrically connected in parallel, each set of anodes providing surfaces oppositely disposed to the surfaces of the other set of anodes to form a chamber coextensive with and surrounding the cathodes, and an electro-magnetic coil surrounding said cathodes and anodes to provide an electro-magnetic field longitudinally of said cathodes and said anodes.

6. A magnetically biased electron discharge device including means for generating a magnetic field, a plurality of electron discharge systems positioned within the magnetic field and including a plurality of straight thermionic cathodes mounted in a circle in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, one set of anodes being exterior of said circle of cathodes and providing a plurality of semi-circular surfaces, the other set of anodes being positioned on the inside of said circle of cathodes and providing a plu-
rality of semi-circular surfaces oppositely dis-
posed to the surfaces of said first set of anodes and cooperating with said first set to substan-
tially surround said cathodes, the exterior set of anodes forming a part of the envelope for said magnetically biased electron discharge device.
7. A magnetically biased electron discharge de-
vice including a plurality of straight thermionic cathodes mounted in a circle in parallel spaced relation and coextensive with each other, a plurality of outer anodes surrounding said cathodes and joined to form a portion of the envelope of the electron discharge device, said anodes pro-
viding a plurality of semi-circular surfaces, a plurality of inner anodes within said cathodes joined to form an inner wall inside said cathodes and having a plurality of semi-circular surfaces oppositely disposed and cooperating with the semicircular surfaces of said outer anodes to pro-
vide a tubular chamber around each of said cathodes, said cathodes being connected in se-
ries, and an electro-magnetic coil positioned on and surrounding the outer anodes to provide a magnetic field for said electron discharge device.
8. A magnetically biased electron discharge de-
vice including, means for generating a magnetic field, a plurality of electron discharge systems positioned within the magnetic field and including a plurality of straight thermionic cathodes mounted in spaced relation and coextensive with each other, two sets of anodes cooperating with said cathodes, said anodes providing semi-cylind-
drical surfaces oppositely disposed and coextensive with and surrounding said cathodes, and concentric transmission lines connected to said anodes.
9. A magnetically biased electron discharge de-
vice including an outer tubular insulating mem-
ber having on its interior surface a plurality of semi-circular depressions, an inner tubular ins-
ulating member having on its exterior surface a plurality of semi-circular depressions oppos-
itely disposed and cooperating with the depre-
sions on said outer tubular member to provide longitudinal tubular chambers, an electrically conducting coating on the surface of the tubular depressions on each of said insulating members, said conducting coatings providing anodes for said electron discharge device, a straight ther-
mionic cathode positioned axially of each of the tubular chambers, the ends of said insulating members being closed to provide a vacuum tight seal and an electro-magnetic coil surrounding the outer insulating member to provide a magnetic field longitudinally of said cathodes and anodes.

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