

Jan. 1, 1946.

G. HECHT ET AL

2,391,967

WAVE GENERATOR

Filed Jan. 27, 1943

FIG. 4

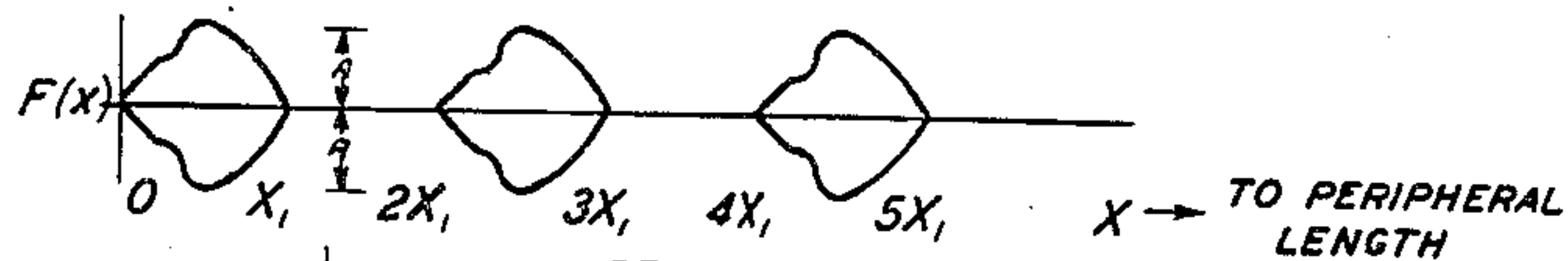


FIG. 5

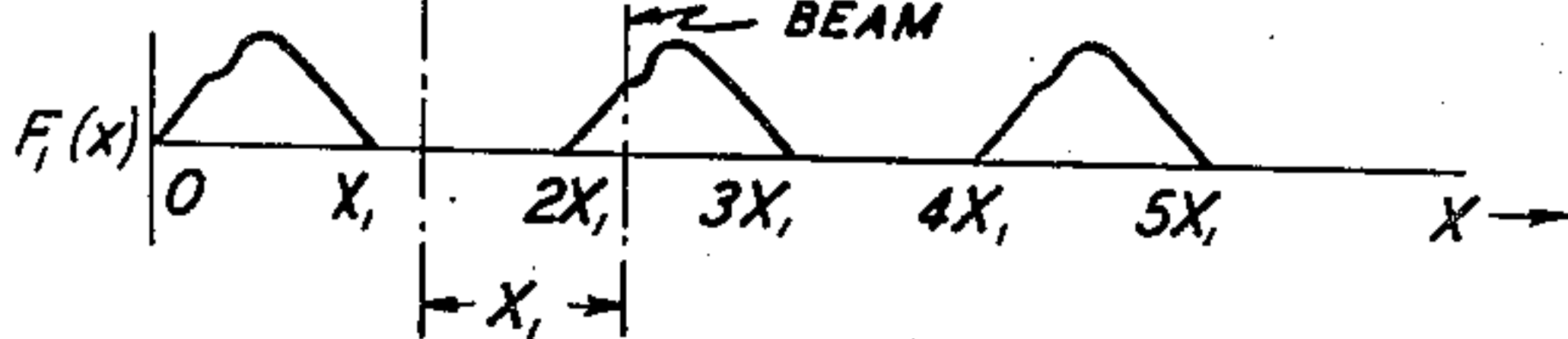


FIG. 6

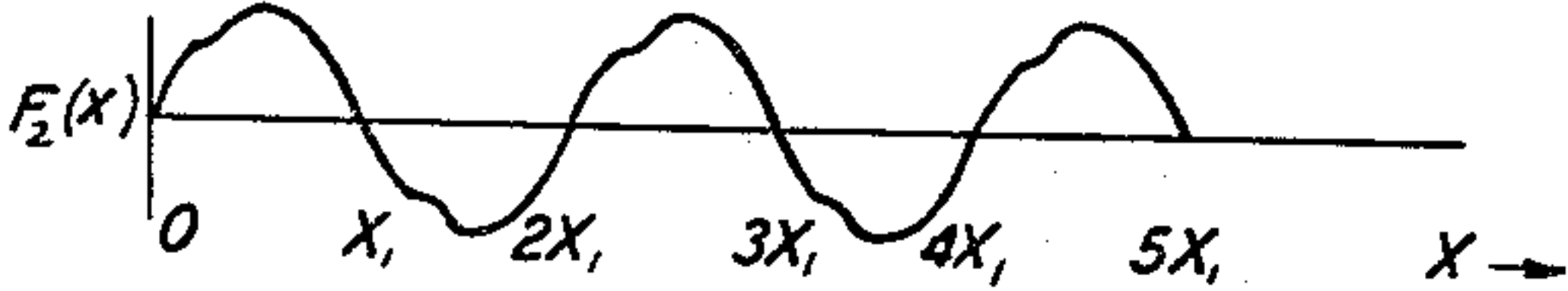


FIG. 7

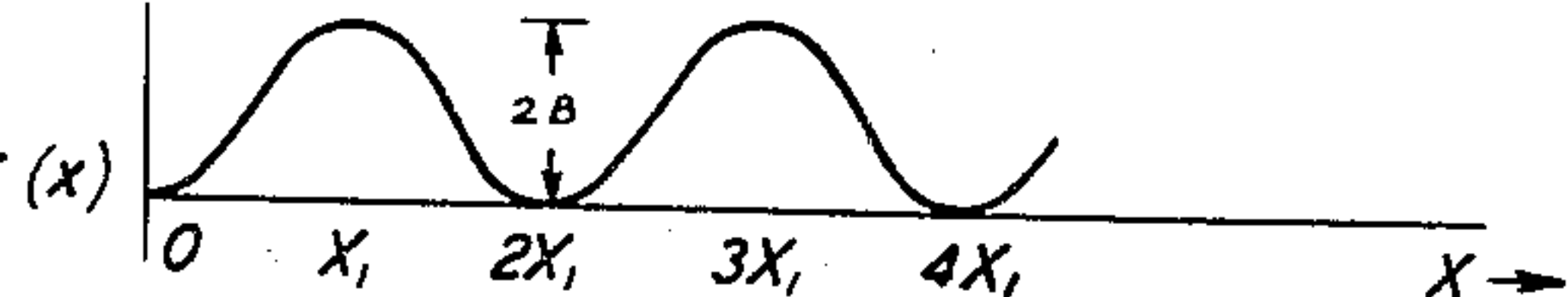


FIG. 8

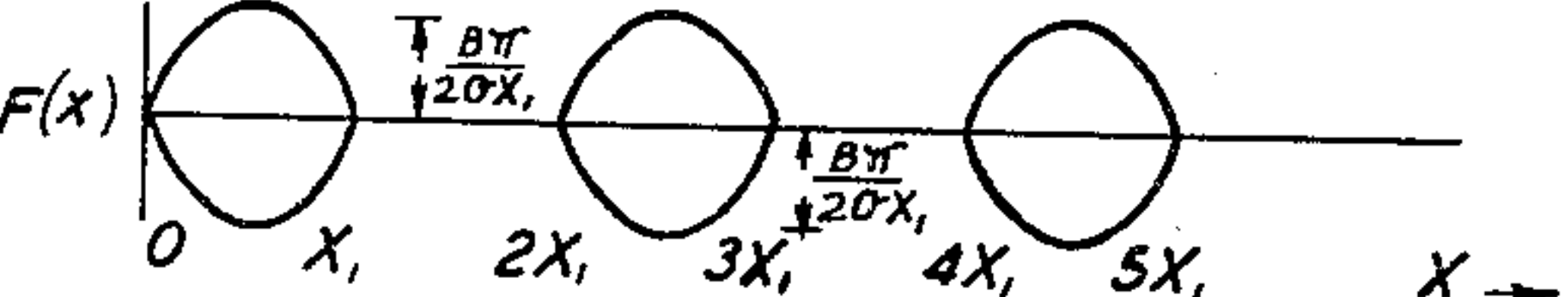


FIG. 9

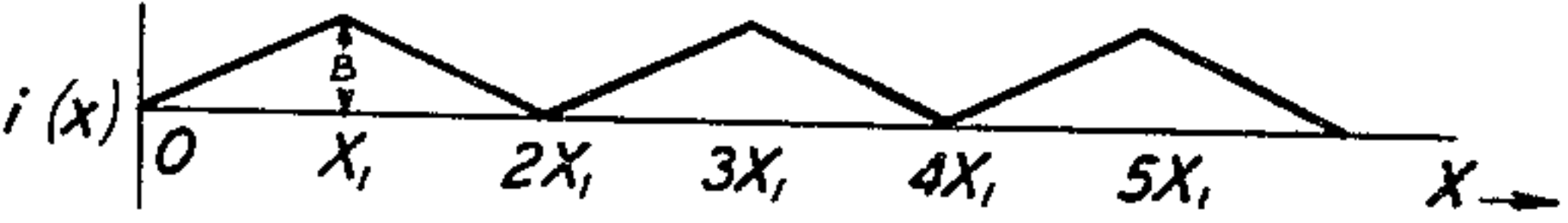


FIG. 10

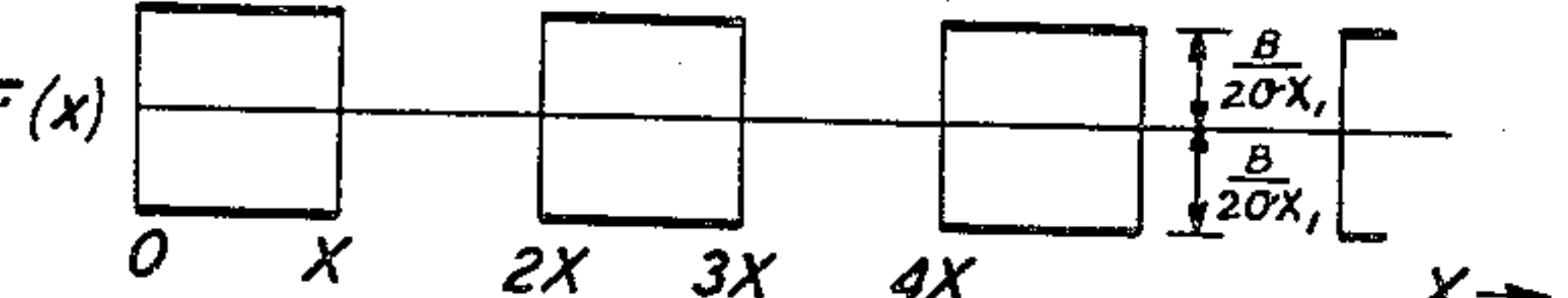


FIG. 11

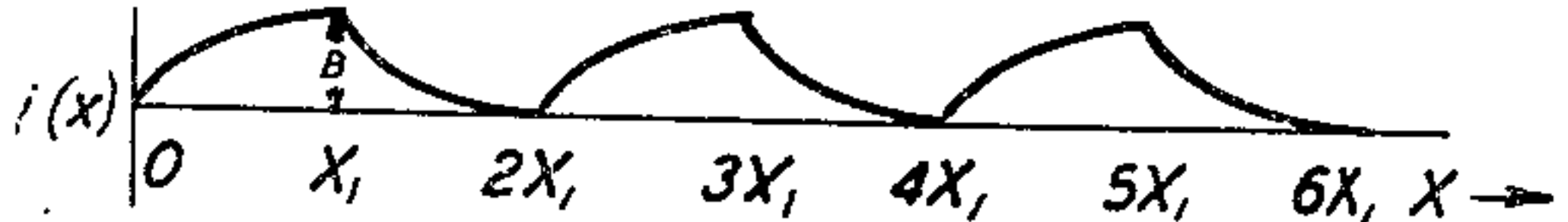


FIG. 12

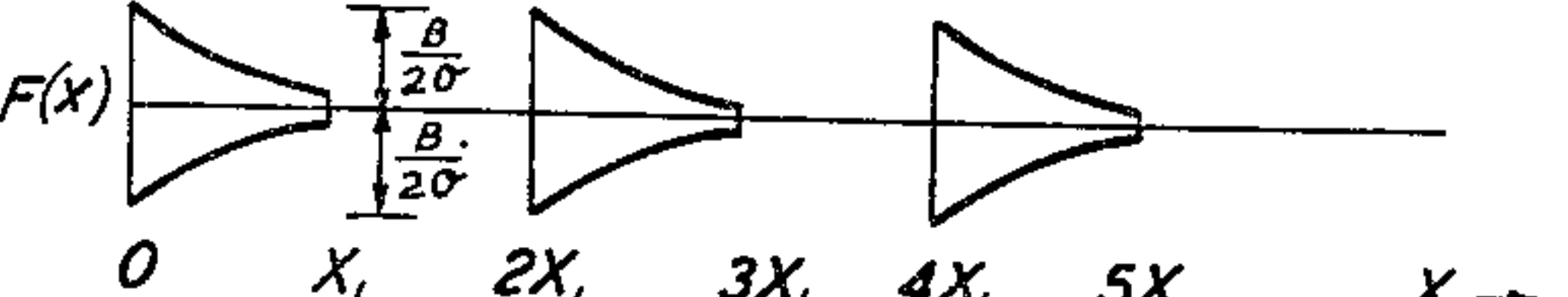


FIG. 1

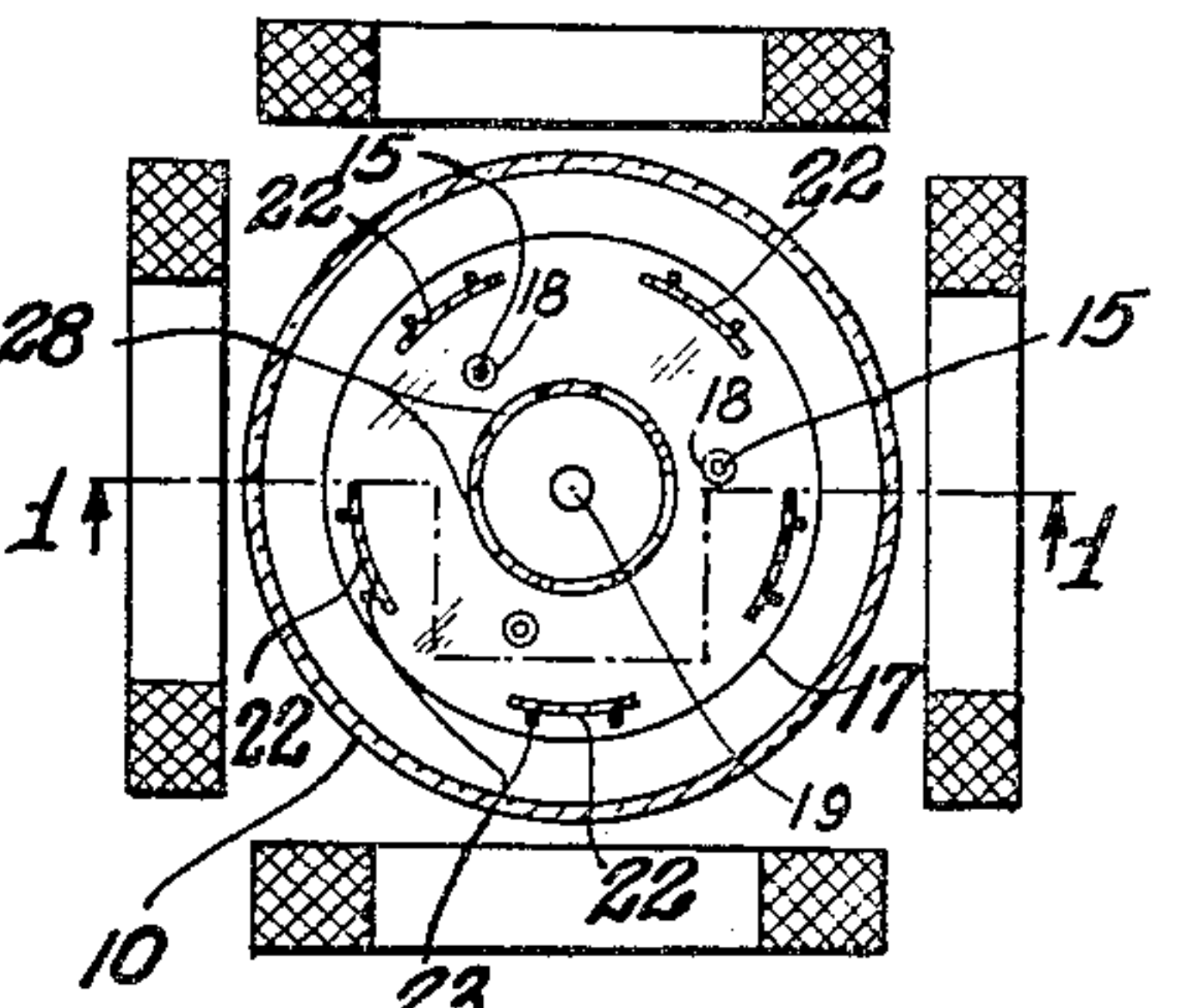
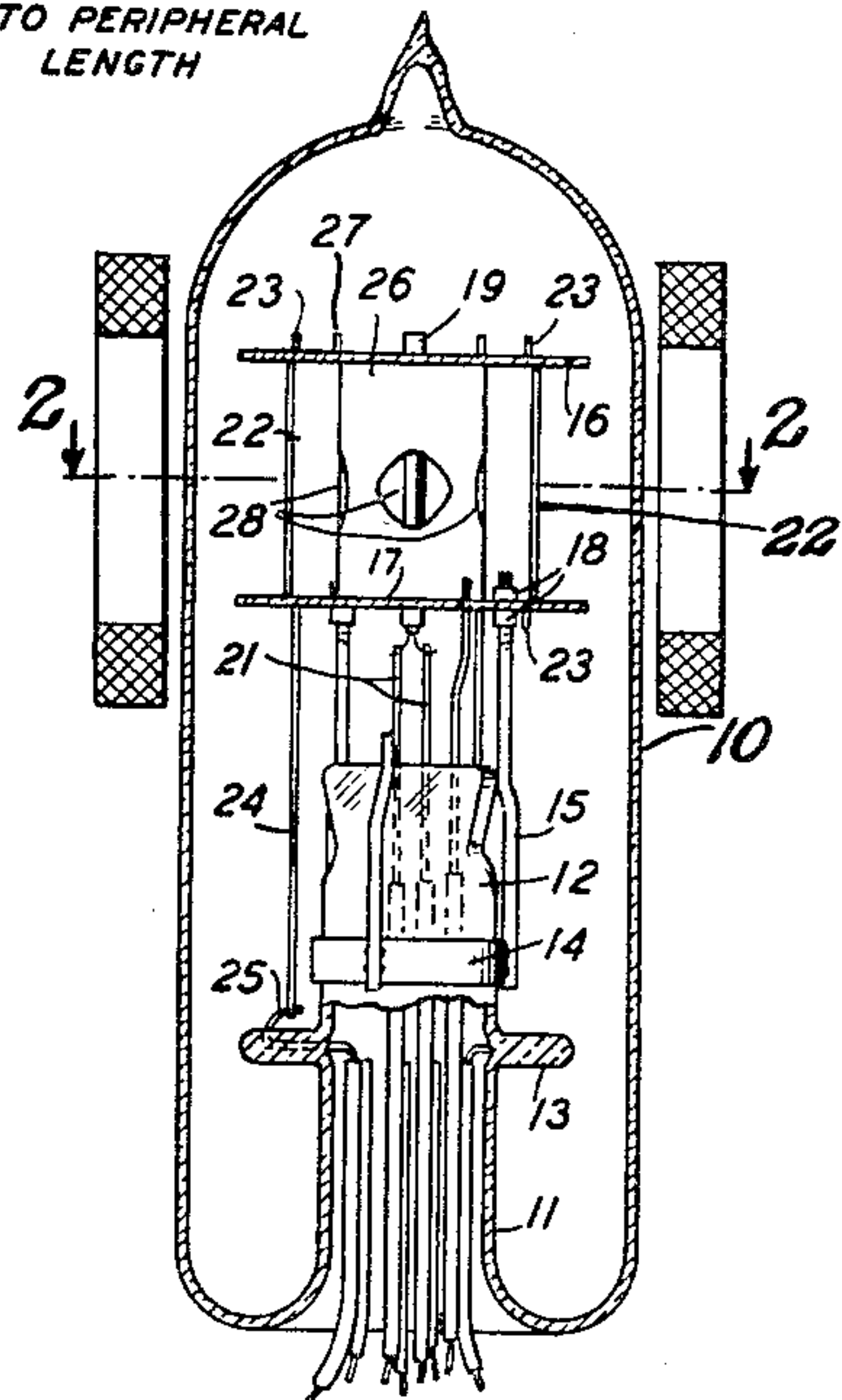
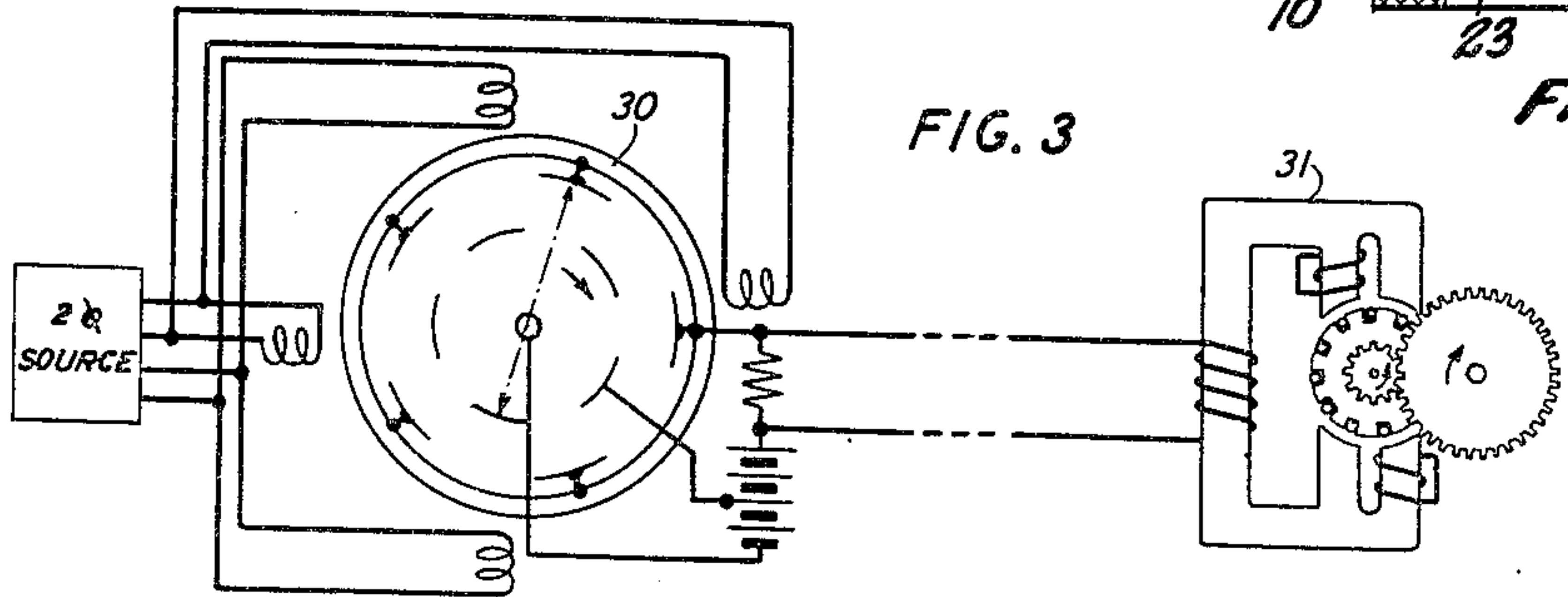


FIG. 3



INVENTORS
G. HECHT
A. A. LUNDSTROM
BY
P. C. Smith

ATTORNEY

UNITED STATES PATENT OFFICE

2,391,967

WAVE GENERATOR

George Hecht, Astoria, N. Y., and Alexis A. Lundstrom, East Orange, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 27, 1943, Serial No. 473,696

4 Claims. (Cl. 250—27.5)

This invention relates to alternating current generators and has for its object to provide novel means for generating alternating currents of desired characteristics.

United States Patent 2,217,774 granted to A. M. Skellett on October 15, 1940, discloses an electron discharge device in which a focussed beam of electrons is rotated by means of a rotating field. A structure of this type comprises an elongated cathode and a plurality of targets or anodes mounted in a cylindrical boundary encompassing the cathode and coaxial therewith. The rotating field concentrates the electrons emanating from the cathode into two beams which are focussed to form electron images of the cathode upon two diametrically opposite targets. As the field rotates the images are shifted accordingly so that the electron beams impinge upon the targets in succession.

In accordance with the present invention, a cylindrical screen is inserted between the cathode and anodes, the screen having openings or windows therein of predetermined form, thereby creating a current in the output of the tube which is a function of the shape of the window.

In particular the invention contemplates the generation of a current of pure sine wave form by the use of windows having contours following the law

$$y = \pm b \cos \frac{\pi}{2} \frac{x}{a}$$

These and other features of the invention will be more clearly understood from a consideration of the following description, in which:

Fig. 1 shows a side view of a section along the line 1—1 of Fig. 2 of an electron discharge device embodying the invention;

Fig. 2 is a view in section along the plane 2—2 of Fig. 1;

Fig. 3 is a circuit diagram employing a tube like that of Fig. 1 as a generator;

Figs. 4, 5, 6, 8, 10 and 12 show different forms of windows which may be used; and

Figs. 7, 9 and 11 show wave forms resulting from the use of various windows.

The electron discharge device shown in Figs. 1 and 2 comprises a highly evacuated enclosing vessel having a stem 11 at one end, the stem terminating in a press 12 and having intermediate its ends an annular flange or seal 13. Clamped about the stem 11 is a metallic band or collar 14 having affixed thereto a plurality of metallic uprights or supports 15 which mount a unitary electrode assembly.

The electrode assembly comprises a pair of spaced parallel insulating members 16 and 17, the lower disc 17 being secured to the uprights 15 by nuts 18. Extending between the discs 16 and 17 and fitted in central apertures therein is a linear cathode 19, which, as shown, may be of the indirectly heated equipotential type comprising a cylindrical metallic sleeve, a portion of the outer surface of which is coated with thermionic material. Electrical connection to the cathode 19 and to the heater element (not shown) therefor may be established through leading-in conductors 21 sealed in the press 12. It will be understood, of course, that other forms of cathodes may be utilized.

A plurality of similar, arcuate sheet metal targets or anodes 22 are mounted between the insulating members 16 and 17 and in a cylindrical boundary coaxial with the cathode 19. The targets or anodes are held in position, equally spaced from one another, by short wires or pins 23 fixed thereto and fitted into apertures in the insulating members 16 and 17. While these anodes 22 may rest against the insulating members, they need only be slightly wider than the windows 28 in the shield 26. Individual electrical connections to the targets 22 may be established through wires 24 connected to the leading-in conductors 25 sealed in the flange 13.

Disposed between the cathode 19 and the anodes 22 is a cylindrical screen 26 which is held in position by short wires 27 in a manner similar to the targets 22. In the screen 26 are a series of windows 28, the contour of which is determined as set forth hereinafter.

During operation of the device, the targets or anodes 22 are maintained at a moderately high positive potential with respect to the cathode 19. The screen may be maintained at a potential intermediate that of the cathode 19 and the anodes 22. Means is provided for producing a uniform magnetic field between the cathode 19 and the targets or anodes 22, resulting in two diametrically opposite radial electron beams parallel to the lines of force of the magnetic field. Reference may be made to the above-identified Skellett patent for a detailed discussion of the operation of the tube.

While, for clarity, only five windows 28 and targets 22 have been shown, any odd number of them may be employed, the use of an odd number avoiding the necessity of suppressing one of the beams. The targets 22 preferably are connected together to form a single collector plate. As the electron beam rotates it alternately passes through each

of the windows to the collector plate. This repeated passage of the electron beam through the windows to the collector plate constitutes a pulsating electric current. The strength or amplitude of the current is determined by the number of electrons passing through a given window at any instant.

According to the present invention, by shaping the contour of the windows a great variety of current waves can be obtained including a pure sine wave as above stated. The exact shape of the windows to derive a particular wave shape can readily be calculated as will be shown hereinafter.

To illustrate the manner in which this is accomplished, let us consider that the screen or baffle containing the windows is cut and laid out as a flat sheet as shown in Fig. 4.

Assume:

- (a) The shape of each of the windows is the same.
- (b) The width of the beam=maximum width of each window=minimum width between windows.
- (c) The height of the beam is greater than the height of the windows.
- (d) The window is symmetrical about the x axis.

To simplify the problem, let us consider only the upper half of each window as in Fig. 5. This does not change the shape of the current picked up by the collector plate, but only reduces the amplitude at every point to one-half. Thus, if $i(x)$ is the current wave for Fig. 4 and $i_1(x)$ is the current wave of Fig. 5

$$i_1(x) = \frac{1}{2}i(x) \quad (1)$$

where x is the right-hand edge of the electron beam.

In Fig. 5, if $F_1(x)$ is the function which defines the contour of the windows, then by integration, the current wave can be expressed as:

$$i_1(x) = \sigma \int_{x-x_1}^x F_1(x) dx = \sigma \left[\int_0^x F_1(x) dx - \int_0^{x-x_1} F_1(x) dx \right] \quad (2)$$

in which σ =the current per unit cross-sectional area of the beam.

Equation 2 shows that the current wave increases to a maximum and then decreases to a minimum, the decrease being an image of the increase. This can be shown by considering the decrease as a negative area below the x axis in the window contour between each positive area which represents the increasing part of the current wave as described in $F_2(x)$ in Fig. 6. Then the current wave $i_1(x)$ is obtained by integrating $F_2(x)$ from 0 to x and Equation 2 is simplified to

$$i_1(x) = \sigma \int_{x-x_1}^x F_1(x) dx = \sigma \int_0^x F_2(x) dx \quad (3)$$

It can be seen that

$$F_2(x) = F_1(x)$$

in the intervals

$$\begin{aligned} 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1, \text{ etc.} \end{aligned} \quad (4)$$

and

$$F_2(x) = -F_1(x-x_1)$$

in the intervals

$$\begin{aligned} x_1 &\leq x \leq 2x_1 \\ 3x_1 &\leq x \leq 4x_1, \text{ etc.} \end{aligned}$$

Differentiating both sides of Equation 3

$$F_1(x) = \frac{1}{\sigma} \frac{di_1(x)}{dx} \quad (5)$$

From Fig. 4 and Fig. 5 we see that

$$F(x) = \pm F_1(x) \quad (6)$$

And from Equations 4 and 6

$$F(x) = \pm F_2(x) \quad (7)$$

for the intervals

$$\begin{aligned} 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1 \\ 4x_1 &\leq x \leq 5x_1, \text{ etc.} \end{aligned}$$

Now substituting Equations 1 and 7 into 5 we have

$$F(x) = \pm \frac{1}{2\sigma} \frac{di(x)}{dx} \quad (8)$$

for the intervals

$$\begin{aligned} 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1, \text{ etc.} \end{aligned}$$

Equation 8 is the fundamental design formula for finding $F(x)$, the function defining the contour of the windows for a desired current wave $i(x)$.

Since the contour function is proportional to the derivative or slope of the current wave, some theoretical and practical limitations are imposed on the kind of current wave which can be derived from the wave generator. Specifically, the slope of $i(x)$ must be finite; that is,

$$\frac{di(x)}{dx} < \infty \quad (9)$$

Since the device does not reverse the flow of electrons, $i(x)$ must be ≥ 0 .

Within the foregoing limitations, however, a wide variety of current waves can be obtained as will be seen from the following examples:

I.—Assume a desired cosine (or sine) wave as shown in Fig. 7,

$$i(x) = B \left(1 - \cos \frac{\pi x}{x_1} \right) \quad (10)$$

from Equation 8, we find

$$\begin{aligned} F(x) &= \pm \frac{B}{2\sigma x_1} \sin \frac{\pi x}{x_1} \\ 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1 \\ 4x_1 &\leq x \leq 5x_1, \text{ etc.} \end{aligned} \quad (11)$$

and the outline of the windows to give the current wave of Fig. 7 is shown in Fig. 8.

II.—For a triangular wave such as shown in Fig. 9

$$i(x) = \frac{xB}{x_1} \quad (12)$$

for

$$\begin{aligned} 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1, \text{ etc.} \end{aligned}$$

and

$$i(x) = B - \frac{xB}{x_1}$$

for

$$\begin{aligned} x_1 &\leq x \leq 2x_1 \\ 3x_1 &\leq x \leq 4x_1, \text{ etc.} \end{aligned}$$

Substituting (12) in (8) we find

$$\begin{aligned} F(x) &= \pm \frac{B}{2\sigma x_1} \\ 0 &\leq x \leq x_1 \\ 2x_1 &\leq x \leq 3x_1 \end{aligned} \quad (13)$$

The shape of the windows for the triangular wave is shown in Fig. 10.

III. For a current wave which rises and falls exponentially as illustrated by Fig. 11,

$$\begin{aligned} i(x) &= B(1 - e^{-x}) \\ \text{for } 0 \leq x \leq x_1 \\ \text{and } 2x_1 \leq x \leq 3x_1, \text{ etc.} \end{aligned} \quad (14)$$

$$i(x) = B[(1 - e^{-x_1}) - (1 - e^{-(x-x_1)})] = B[e^{-(x-x_1)} - e^{-x_1}]$$

$$\begin{aligned} \text{for } x_1 \leq x \leq 2x_1 \\ 3x_1 \leq x \leq 4x_1, \text{ etc.} \end{aligned}$$

substituting (14) in (8)

$$F(x) = \pm \frac{B}{2\sigma} e^{-x} \quad (15)$$

$$\begin{aligned} \text{for } 0 \leq x \leq x_1 \\ 2x_1 \leq x \leq 3x_1 \end{aligned}$$

and the contour of the windows for this current wave is shown in Fig. 12.

Individual pulses or groups of pulses of any of these waves can be obtained by establishing separate connections to the individual anodes associated with each window.

This electronic wave generator can be employed as a sine wave oscillator, as a frequency code generator for alternating current signaling, as well as a number of other such applications.

In Fig. 3 tube 30 is a tube embodying the present invention serving as a source of sine wave alternating current for driving an induction type motor 31. Such motors are well known and may be used for a variety of purposes.

What is claimed is:

1. Electron discharge apparatus for generating an electric current which has a predetermined wave form comprising an evacuated vessel containing a cathode, a plurality of anodes symmetrically mounted in a cylindrical boundary encompassing said cathode, a direct current source connected between said cathode and said anode for producing an electron emanation from said cathode, coils mounted around said vessel and connected to a source of two-phase alternating current for producing a continuously and uniformly rotating magnetic field for focussing electrons emanating from said cathode upon each of said anodes in succession, and a cylindrical shield member mounted between said cathode and said anodes, said shield member having a plurality of openings therein, there being an opening opposite each of said anodes each opening having a contour following the same predetermined mathematical formula and each opening separated from the adjacent opening by a distance equal to the horizontal dimension of said opening.

2. Electron discharge apparatus for generating an electric current which is a sine wave, comprising an evacuated vessel containing a cathode, a plurality of anodes symmetrically mounted in a cylindrical boundary encompassing said cathode, a direct current source connected between said cathode and said anode for producing an electron emanation from said cathode, coils mounted

around said vessel and connected to a source of two-phase alternating current for producing a continuously and uniformly rotating magnetic field for focussing electrons emanating from said cathode upon each of said anodes in succession, and a cylindrical shield member mounted between said cathode and said anodes, said shield member having a plurality of openings therein, there being an opening opposite each of said anodes each opening having a contour following the law

$$y = \pm b \cos \frac{\pi}{2} \frac{x}{a}$$

in which a and b are constants and x and y are the horizontal and vertical dimensions of said openings.

3. Electron discharge apparatus for generating an electric current which is a sine wave, comprising an evacuated vessel containing a cathode, an uneven number of anodes symmetrically mounted in a cylindrical boundary encompassing said cathode, a direct current source connected between said cathode and said anode for producing an electron emanation from said cathode, coils mounted around said vessel and connected to a source of two-phase alternating current for producing a continuously and uniformly rotating magnetic field for focussing electrons emanating from said cathode upon each of said anodes in succession, and a cylindrical shield member mounted between said cathode and said anodes, said shield member having a plurality of openings therein, there being an opening opposite each of said anodes each opening having a contour following the law

$$y = \pm b \cos \frac{\pi}{2} \frac{x}{a}$$

and separated from the adjacent openings by a distance x , in which a and b are constants and x and y are the horizontal and vertical dimensions of said openings.

4. A sine wave generator comprising a rotary beam electron discharge device having a cathode, a plurality of anodes symmetrically mounted around said cathode, and an output circuit and means for varying the current in said output circuit in accordance with a sine wave comprising a cylindrical shield member mounted between said cathode and said anodes, said shield member having a plurality of openings therein, there being an opening opposite each of said anodes, each opening having a contour following the law

$$y = \pm b \cos \frac{\pi}{2} \frac{x}{a}$$

and separated from the next opening by a distance x , in which a and b are constants and x and y are the horizontal and vertical dimensions of said openings.

GEORGE HECHT.
ALEXIS A. LUNDSTROM.