R. A. FESSENDEN.

METHOD OF AND APPARATUS FOR REPRODUCING IMPULSES.

APPLICATION FILED FEB. 9, 1914.

1,133,435.

Patented Mar. 30, 1915.

2 SHEETS—SHEET 1.

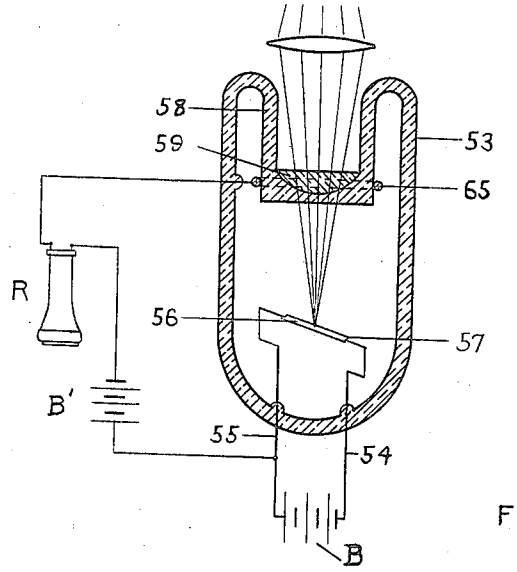

FIG. 1.

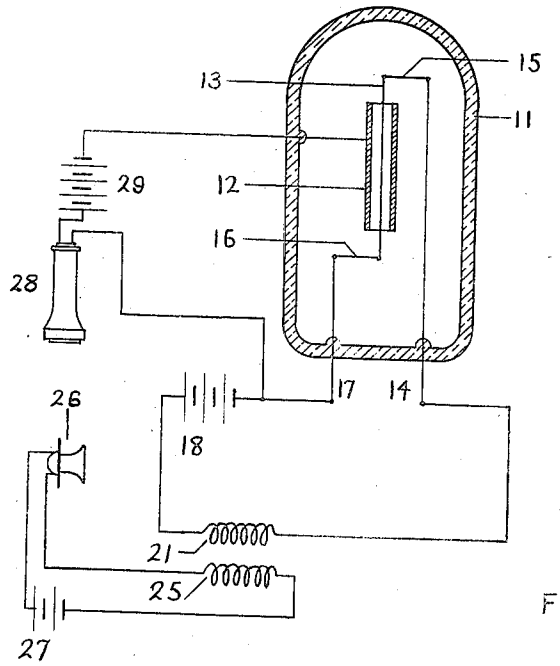

FIG. 2.

WITNESSES:

Patrick J. Conroy.

E. B. Tomlinson.

INVENTOR

Reginald A. Fessenden

BY

Brownell & Woodworth

ATTORNEYS

R. A. FESSENDEN.

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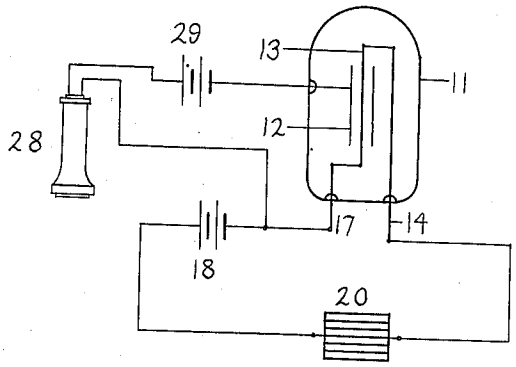

FIG. 3

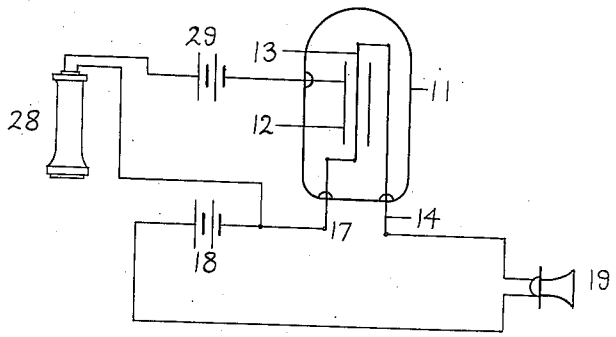

FIG. 4

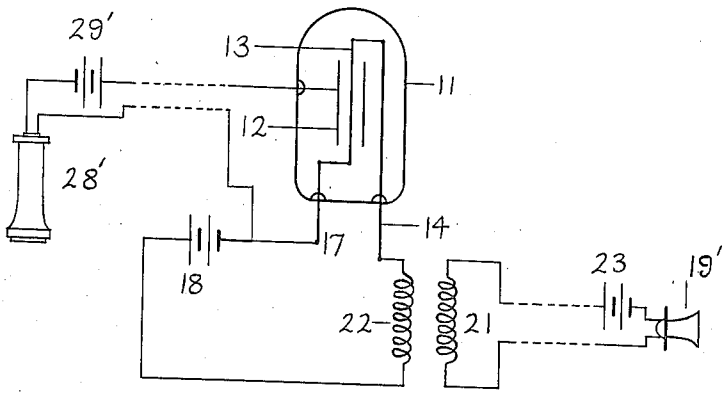

FIG. 5

WITNESSES:

Patrick J. Conroy.

E. B. Tomlinson.

INVENTOR

Reginald A. Fessenden

BY

Browne & Woodworth

ATTORNEYS.

UNITED STATES PATENT OFFICE.

REGINALD A. FESSENDEN, OF BROOKLINE, MASSACHUSETTS.

METHOD OF AND APPARATUS FOR REPRODUCING IMPULSES.

1,133,435. Specification of Letters Patent. Patented Mar. 30, 1915.

Application filed February 9, 1914. Serial No. 817,453.

To all whom it may concern:

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, and a resident of Brookline, in the county of Norfolk and State of Massachusetts, have invented a new and useful Improvement in Methods of and Apparatus for Reproducing Impulses, of which the following is a specification.

My invention relates to the reproduction, either with or without amplification and with or without change of form, of impulses, such for example, as sound impulses, electrical impulses, et cetera, and, although obviously of more general application, it may be used to reproduce and also to amplify by means of light and heat phonographically recorded sounds.

My method, broadly speaking, is based upon the fact, as more fully explained by me in a paper printed in the *Astrophysical Journal* for December, 1906, that if the cathode of a vacuum tube be heated, negative electricity is emitted therefrom. I have found that if the temperature of said cathode be varied, similar variations of considerable amplitude will be created in the electrical current flowing in a circuit, the terminals of which are connected respectively to the anode and cathode of said tube; and I have found also that when such temperature variations are made in accordance with impulses of light, heat, electricity, et cetera, the sounds reproduced by an electroresponsive device in series with said anode and cathode, may, by suitably proportioning the tubes and electrodes, be made to vary in accordance with the original sounds initiating such impulses of light, heat, electricity et cetera.

The drawings which accompany and form a part of this specification illustrate several forms of apparatus and arrangements of circuits whereby my improved method may be realized in practice; but my invention is broader than the particular apparatus shown, and may be practised with a variety of devices and systems of circuits.

In the drawings,—Figure 1 is a sectional view of a vacuum tube with its associated circuits shown in diagram, constructed and arranged in accordance with one embodiment of my invention. Fig. 2 is a similar view of a modification. Figs. 3, 4 and 5 are diagrammatic views of other modifications of the system shown in Fig. 2.

In the particular drawings selected to illustrate the principle of my invention, 53 is a tube into which is sealed a smaller tube 58, flattened and polished to a plane surface at its lower end on its under side and rough-ground on its upper side. A piece of optical glass 59 having its upper surface plane and polished, is inserted as shown in the tube 58, and a suitable fluid such as Canada balsam is used to fill the space between the rough-ground or unground upper surface of the tube 58 and the lower surface of the glass piece 59. The tube so formed is then evacuated and constitutes a vacuum tube having a true optical window. While it will be understood that I do not limit myself specifically to this way of producing a vacuum tube having a true optical window, nevertheless I have found this procedure convenient for overcoming the difficulty that has heretofore existed in making such devices. Platinum wires 54, 55 are sealed into the tube and carry between them, preferably on a slant as shown, a conducting member, such for example as a piece of platinum foil 57, which may be provided with a thin coating 56 of a salt of calcium or barium, or other substance which has the property of readily giving out electrons when heated. The platinum foil constitutes one electrode of the vacuum tube, and the ring 65, which may also be of platinum, the other. The platinum foil 57 being heated by current from a suitable source of energy such as the battery B, a small current flows through the vacuum tube and through the external circuit, which includes the electroresponsive device R, herein shown as a telephone receiver, and the source of electrical energy B′, herein shown as a battery, and which has its terminals connected with the electrodes of the vacuum tube.

The operation is as follows: When light is focused upon the platinum foil 57, the current flow through the tube and external circuit increases greatly and to an extent depending upon the amount of the light. Inasmuch as the current in the vacuum tube and external circuit varies in accordance with such variation in light and as the indication produced by the receiver R varies according to the current flowing through the same, said receiver will reproduce a phono-

graphic record, and if sufficient light is used, will amplify the same, if the light be caused to vary in accordance with said record in the manner shown in my application Serial No. 635,362, filed June 26, 1911, or in any other suitable manner.

In Fig. 2, 11 represents a vacuum tube, in which is located an anode 12 of conducting material, which wholly or partly surrounds the cathode 13 and preferably is in the form of a tube of any convenient diameter, but preferably relatively small, such for example, as one millimeter in diameter, although it may be as large as one inch in diameter. The conductors 14, 17 are sealed into the vacuum tube and support the cathode 13, preferably by means of spring portions 15, 16, to maintain the cathode in its proper position under very light tension. The cathode is shown in the present instance as consisting of a strip of very fine wire or foil of any suitable cathode material, such for example as tungsten, platinum, molybdenum, or the like, and the anode may be of the same or different material. A suitable source of electrical energy, such as the battery 18, is employed to heat the cathode to the desired temperature and such temperature may be varied by varying the current in the circuit containing the cathode by any suitable current-varying device, such, for example, as the telephone transmitter 26, which is inductively associated with the cathode circuit by means of the transformer 21, 25, and which is serially connected with a suitable source of electrical energy such as the battery 27; or by means of the telephone transmitter 19 in series with the cathode, as shown in Fig. 4; or by means of a bolometer or selenium cell 20 as shown in Fig. 3. By speaking into either transmitter, or by causing radiation such as light or heat to change the resistance of the device 20, current variations are produced in the circuit of the cathode and the temperature of the latter is varied, and such variations in temperature will be in accordance with the variations of the impulses of sound, light, or heat employed to vary the resistance of the telephone transmitter, selenium cell, or bolometer, respectively.

When the temperature of the cathode is varied in any of the ways above described, or in any other suitable way, the current flowing in the circuit containing the electroresponsive device 28, source of electrical energy, such as the battery 29, the anode 12, and the cathode 13, will be correspondingly varied and the electroresponsive device will reproduce such variations. It is desirable that the cathode should have small heat capacity so that it will respond to frequencies as high as those of the human voice, and it is also desirable to employ a tubular anode to conserve the heat developed by the passage of the current through the cathode, because thereby less energy is required to produce a given fluctuation in temperature, and the device is more responsive to rapid current variations. It will be understood of course that the impulse reproducing and amplifying device herein described is capable of use in many other relations, where it is desirable to amplify feeble electrical impulses, such for example, as those produced in telephone circuits, or in the production of alternating currents from direct currents, and it is especially useful as a telephone relay or repeater, in which relation it will require none of the more or less complicated circuital arrangements to prevent "back-talking" or "howling." An example of the use of my invention as a telephone repeater is shown in Fig. 5, where 19′ represents a telephone transmitter at one station and 28′ a telephone receiver at a distant station, the vacuum tube and its associated circuits being located at a point intermediate of said stations. In this case, a battery 23 is serially connected with the transmitter 19′ and the primary 21, and the cathode circuit includes the secondary 22 inductively connected with said primary, while the receiver 28′ is connected in series with the battery 29′ and the anode and cathode.

I claim:

1. The method of reproducing impulses which consists in heating the cathode of a vacuum tube, thereby establishing an electrical current in a circuit which includes the electrodes of said tube and an electroresponsive device, varying the temperature of said cathode by means of the impulses to be reproduced, thereby creating variations in the current established in said circuit, and causing said current variations to actuate said electro-responsive device, thereby reproducing said impulses.

2. In a device for reproducing impulses, a vacuum tube, a tubular anode therein, a cathode located within said anode, electrical means for heating said cathode, impulse-actuated means for varying the temperature of said cathode, a circuit including said anode and cathode, and a device in said circuit responsive to the changes of current resulting from such temperature variations.

3. In a device for reproducing impulses, a vacuum tube, a tubular anode, a cathode located within said anode, means for varying the temperature of said cathode in accordance with the impulses to be reproduced, a circuit including said anode and cathode, and a device and source of electrical energy associated with said circuit responsive to the changes of current resulting from such temperature variations.

4. In a device for reproducing impulses, a vacuum tube, a tubular anode therein, a cathode located within said anode, said cath-

ode having small heat capacity, electrical means for heating said cathode, a circuit including said anode and cathode, impulse-actuated means for varying the temperature of said cathode and a device in said circuit responsive to the changes of current resulting from such temperature variations.

5. In a device for reproducing impulses, a vacuum tube, a tubular anode, a cathode located within said anode, said cathode having small heat capacity, means for varying the temperature of said cathode in accordance with the impulses to be reproduced, a circuit including said anode and cathode and a device responsive to the changes of current resulting from such temperature variations and a source of electrical energy associated with said circuit.

6. In a device for reproducing impulses, a vacuum tube, a tubular anode therein, a cathode located within said anode, said cathode having small heat capacity, electrical means for heating said cathode, a circuit including said anode and cathode, impulse-actuated means for varying the temperature of said cathode, a device in said circuit responsive to the changes of current resulting from such temperature variations and a source of electrical energy in said circuit.

In testimony whereof, I have hereunto subscribed my name this 7th day of February, 1914.

REGINALD A. FESSENDEN.

Witnesses:

GEO. K. WOODWORTH,

E. B. TOMLINSON.