Aug. 20, 1940. W. E. KOCK 2,212,292

POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Filed July 22, 1938 5 Sheets-Sheet 1

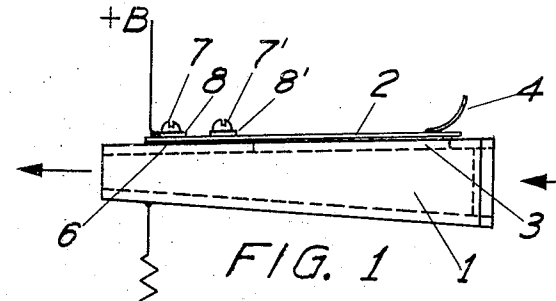


FIG. 1

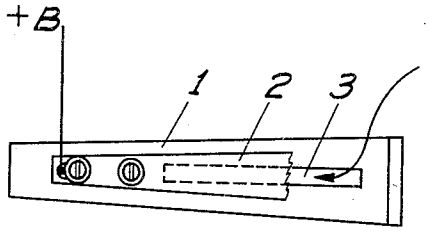
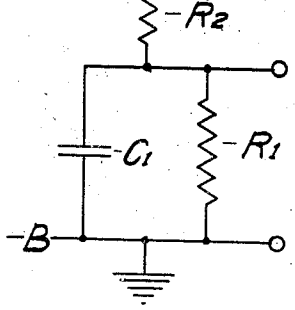


FIG. 2



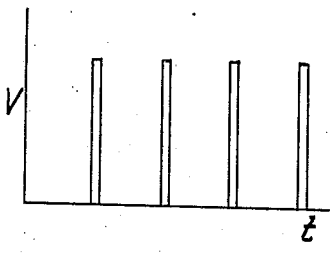


FIG. 3

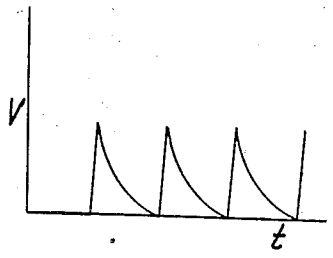


FIG. 4

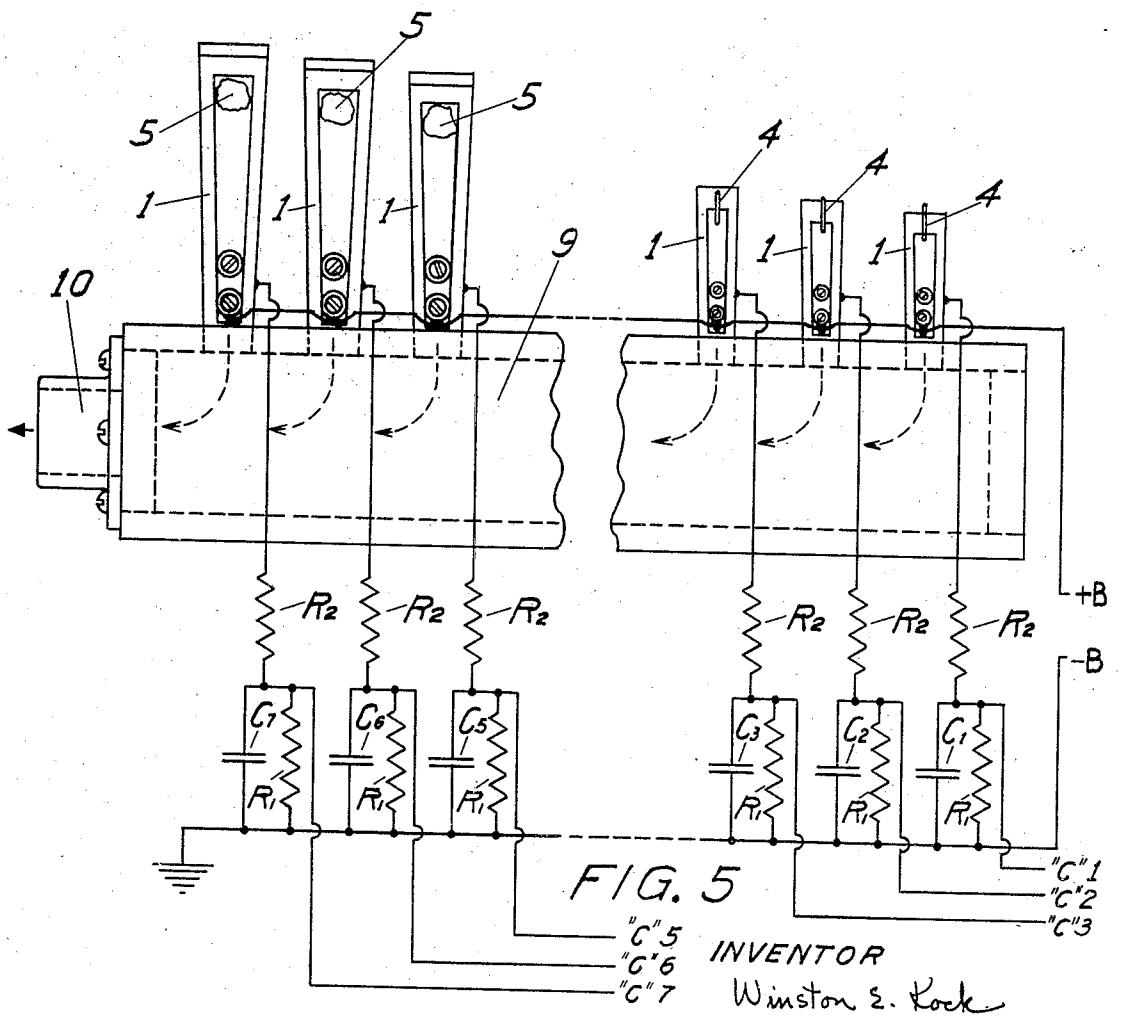


FIG. 5

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Aug. 20, 1940. W. E. KOCK 2,212,292

POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Filed July 22, 1938 5 Sheets-Sheet 2

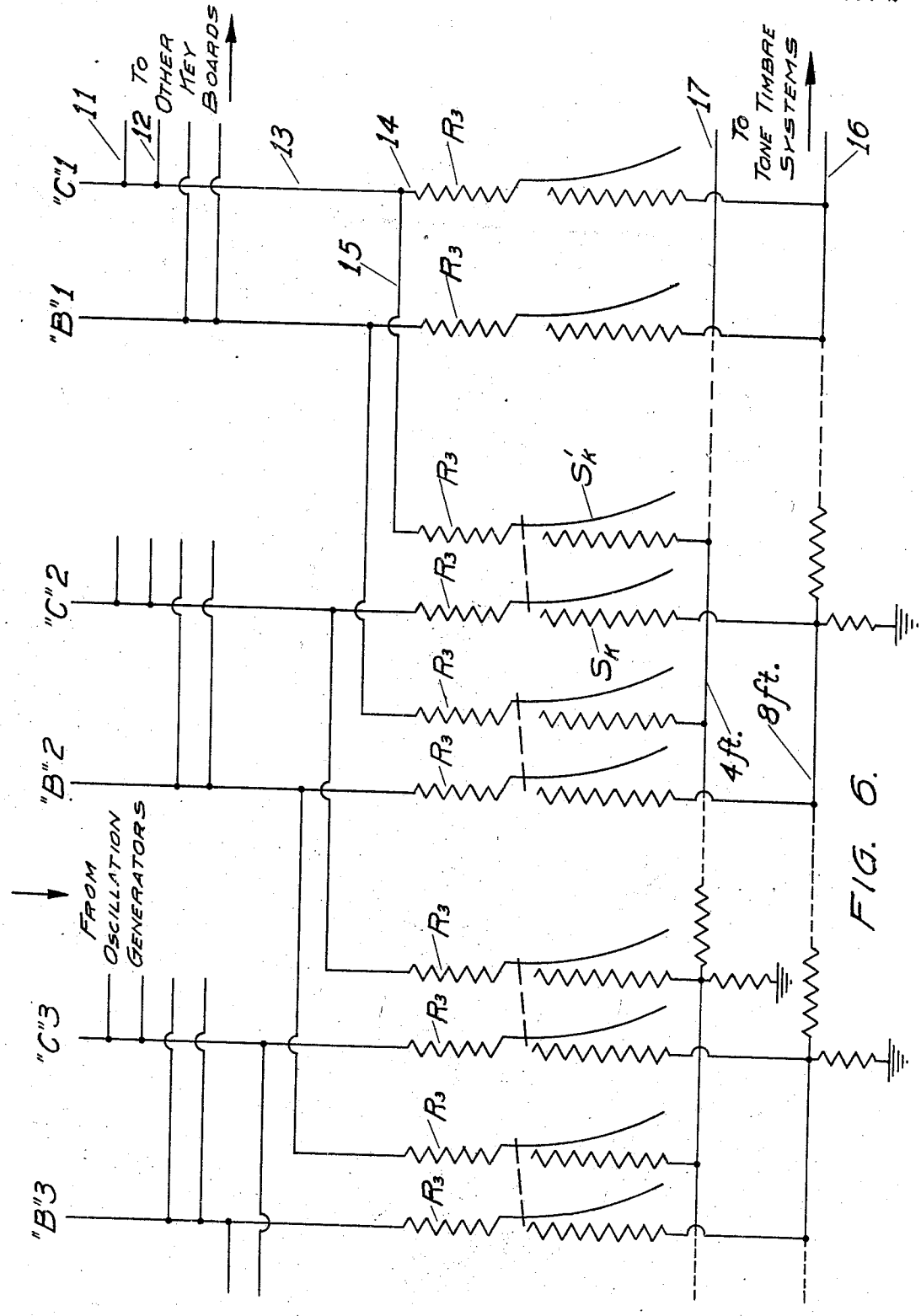


FIG. 6.

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POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Filed July 22, 1938 5 Sheets-Sheet 3

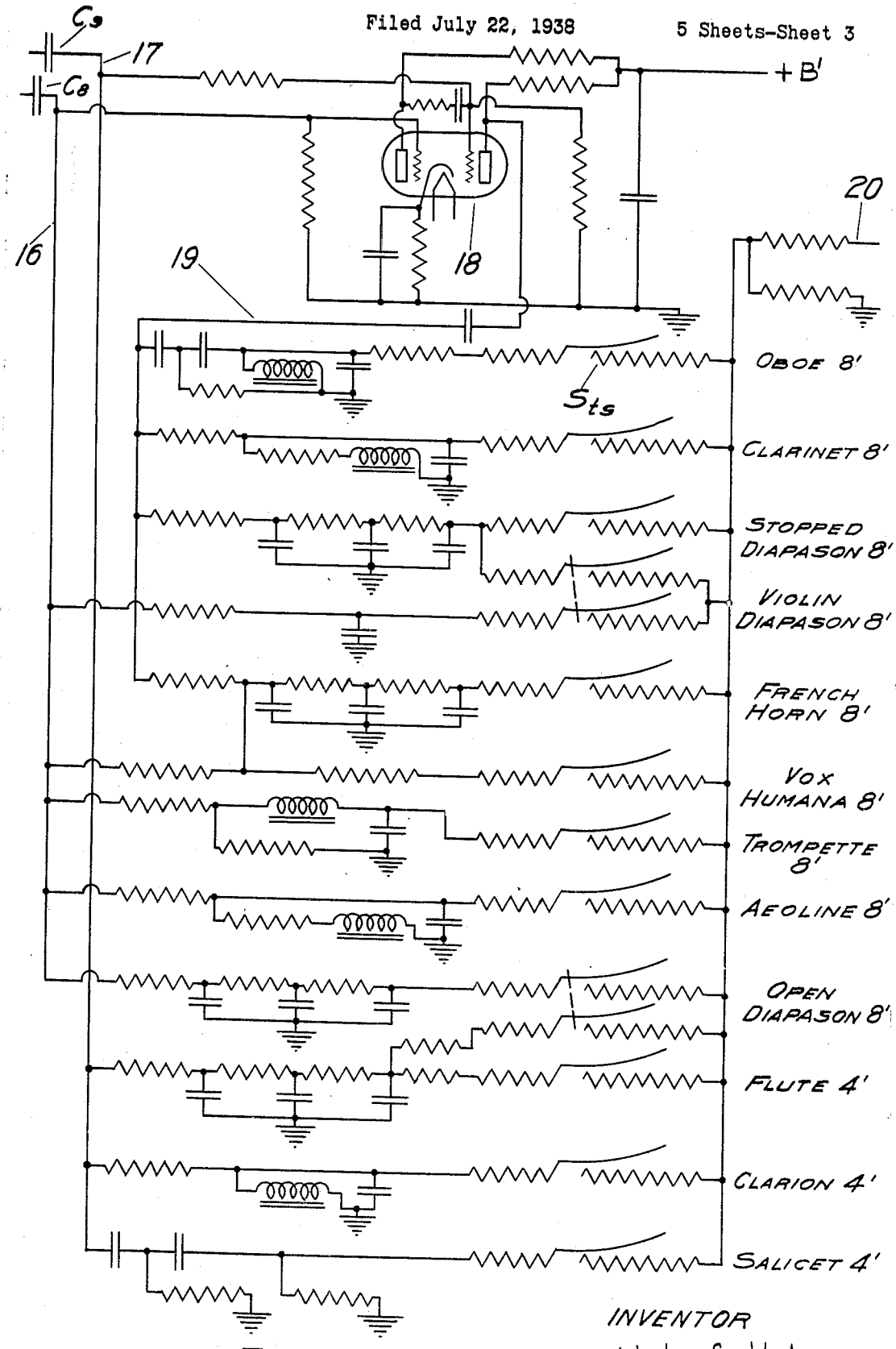


FIG. 7

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POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Filed July 22, 1938 5 Sheets-Sheet 4

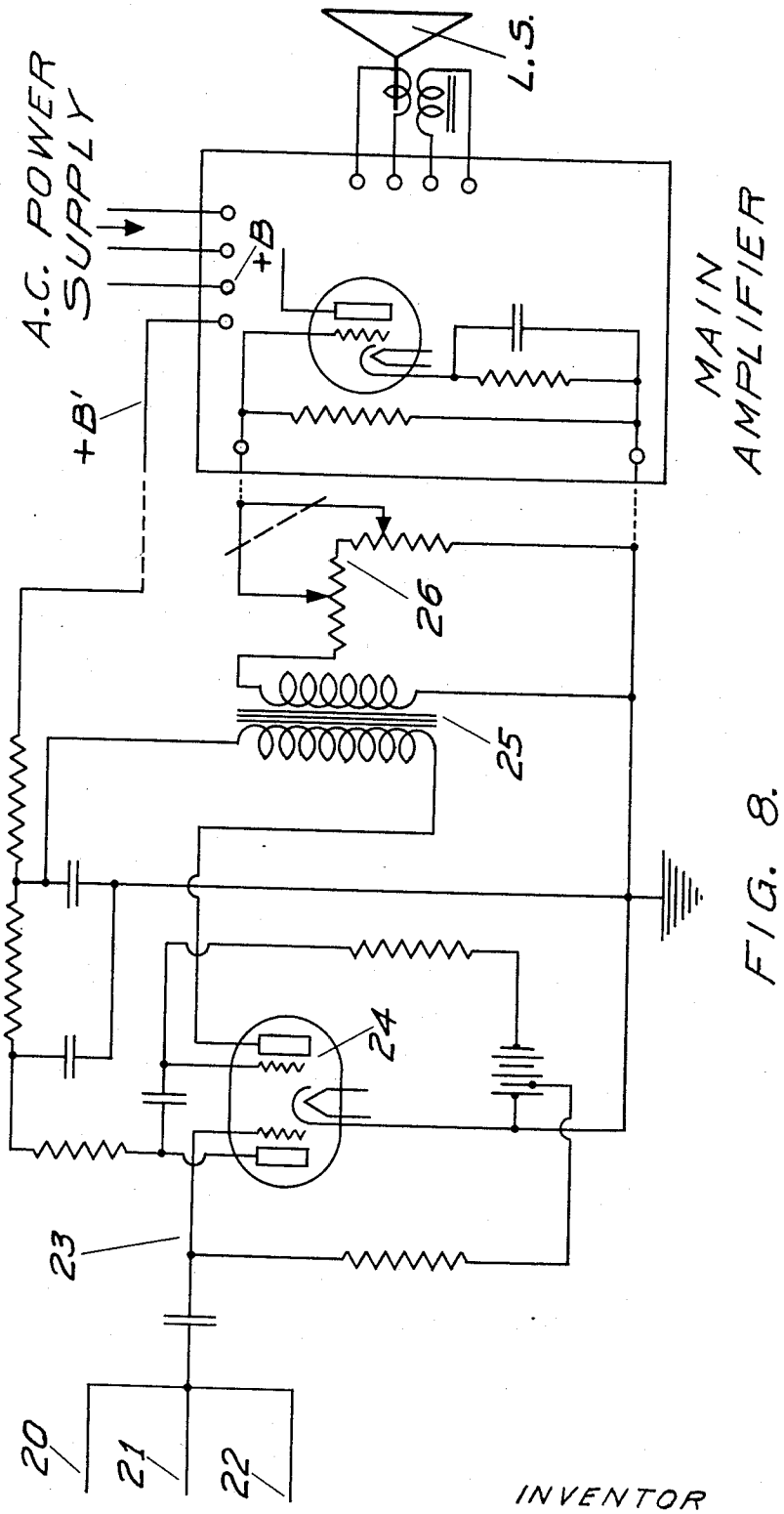


FIG. 8.

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Aug. 20, 1940. W. E. KOCK 2,212,292

POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Filed July 22, 1938 5 Sheets-Sheet 5

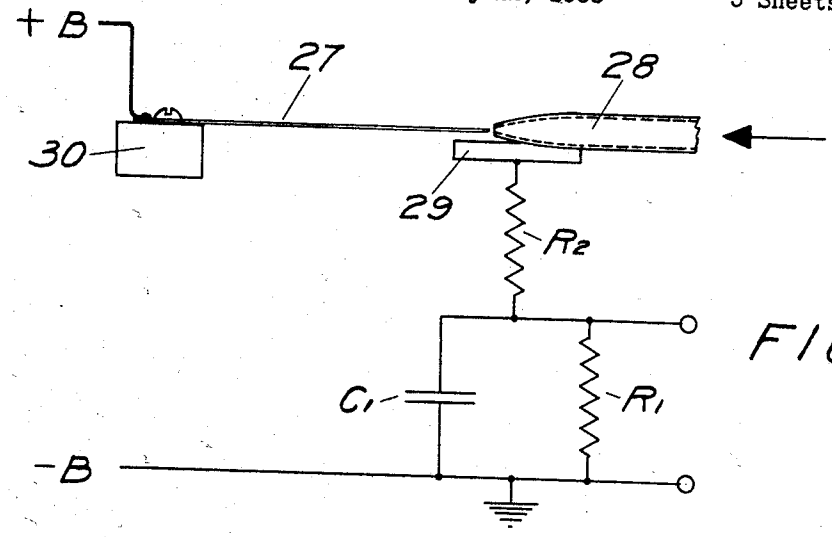


FIG. 9.

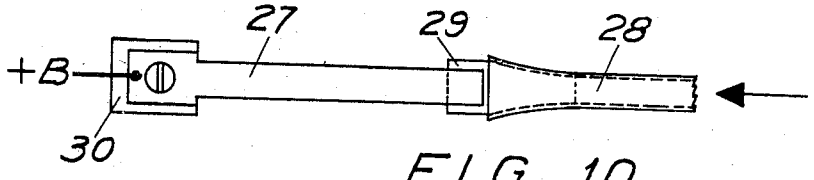


FIG. 10.

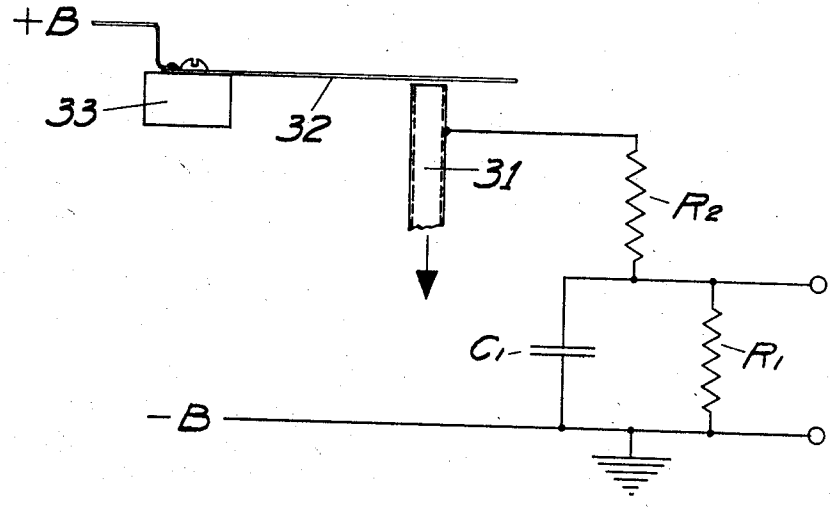


FIG. 11.

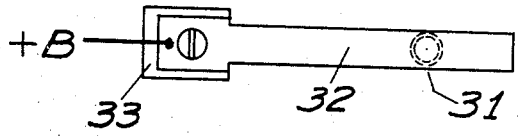


FIG. 12.

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Patented Aug. 20, 1940

2,212,292

UNITED STATES PATENT OFFICE

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POLYPHONIC INSTRUMENT EMPLOYING VIBRATORY MEANS

Winston E. Kock, Cincinnati, Ohio, assignor to The Baldwin Company, Cincinnati, Ohio

Application July 22, 1938, Serial No. 220,717

5 Claims. (Cl. 84—1.04)

This invention has reference to means employing vibrators and fluid, preferably air, actuation therefore, for the production of electric oscillations.

It is an object of the invention to provide in an electric oscillation generator, means for producing oscillations of complex wave forms, corresponding to oscillations rich in harmonics, the pulsations being provided through electric contacts interrupting the motions of fluid operated vibrators, in conjunction with a source of electric potential for the contacts.

As will be set forth more clearly in this description, the generators employed in the present invention are advantageously applicable in the electrical production of music; and thus it is an object of the invention to provide a plurality of these generators suitable in conjunction with the tone color systems set forth in my copending United States patent application Serial No. 196,484, filed March 17, 1938, for improvements in Electrical organs, in the electrical production of polyphonic music of various tone colors.

While in the copending application No. 196,484 a specific way of oscillation generation was set forth exemplarily, it was also disclosed that the broader aspects of that invention were not necessarily limited to the specific generating means described; and thus accordingly it is an object of the present invention to provide an oscillation generating system having the fundamental advantages of cheapness, small space requirements, and a type of construction with which makers of mechanical musical instruments will be generally familiar, which system will operate cooperatively with the tone color systems of the aforementioned application No. 196,484.

Another object of the invention is to provide in the generator, pulsatory oscillations of the peak type, similar to those set forth in the application No. 196,484, as one form of oscillation suitable therefor. With this is an object to provide electrical means for modifying the wave form and thus the harmonic character of these peaked pulses, similar to the means set forth in the aforementioned application No. 196,484.

Specifically it is an object to provide a fluid operated vibratory generator in which the electric contact means resides in the vibrator and in the seat or base therefor.

With these objects in mind and other objects which will occur to those skilled in the art on reading this specification, or will be set forth hereinafter, the invention will now be described in detail, reference being made, for clearness, to the accompanying drawings forming a part hereof, wherein:

Figure 1 is a side view of a vibratory generator, in a horizontal position, this generator employing a beating reed;

Figure 2 is a top view thereof;

Figure 3 is a graph of the wave form of the pulsations produced by the generator;

Figure 4 is a graph of pulsations of a type which may be derived from those of Figure 3 by electrical modification thereof;

Figure 5 is an assembly of generators such as shown in Figure 1, arranged on a wind box;

Figure 6 shows the electrical features of a keyboard system;

Figure 7 represents an electrical tone color system;

Figure 8 is an output and sound reproducing system;

Figure 9 is a side view of another form of vibratory generator;

Figure 10 is a top view thereof;

Figure 11 is a side view of a third form of vibratory generator; and

Figure 12 is a top view thereof.

Referring to Figure 1 wherein a form of electrical generator is illustrated, I have shown a hollow chamber 1 suitable as a support for a metallic reed 2 of sufficient area to cover a slot-like opening 3 in the chamber, the read being supported to be normally spaced apart slightly from the opening 3. The opening 3 is shown in a clearer manner in Figure 2 wherein the free or moving end of the reed 2 has been cut away to expose this opening. Fluid, preferably air, is exhausted from the left or open end of the chamber 1 and thus drawn in through the slot 3—as indicated by the direction arrows in Figures 1 and 2. This motion of fluid causes the reed 2 to vibrate in the manner of a beating reed, the excursions of the reed being interrupted by the base 1, the reed covering the slot 3 on interruption, springing back therefrom by reaction from kinetic energy acquired in its forward motions and by the potential energy of the reed deflection. As is known to those in the musical instrument art, the mechanical vibrations of the beating reed apparatus described may be readily maintained. Hence it requires no further detailed description, and accordingly I have not indicated a pump for moving air through the chamber 1 as such a prime mover may take any of the forms well known in the art.

Reeds such as shown may be operated at various audio frequencies corresponding to

musical pitches, these vibators taking various sizes and shapes according to their particular positions in a musical scale; and for tuning them I have indicated a wire or lug **4** attached to the free end of the reed, this wire being bent or cut to adjust the reed in pitch. I have found this procedure to be advantageous for reeds of higher pitch; for bass reeds I employ a soldered loading or weight **5** at the end of the reed, such as shown in Figure 5, this loading being advantageous in providing low pitched reeds without undue size thereof. In this respect it will be understood that since the primary function of the aforedescribed apparatus is to produce electric oscillations, the sound output therefrom may be insignificant—hence my reeds may be much smaller than those in a mechanical musical instrument. Furthermore, I have found it preferable to soundproof an assemblage of these vibratory generators such as shown in Figure 5 by a suitable covering box, not shown.

With respect to the electrical aspects of the reed generator of this description, a strip of insulative material such as mica **6** is interposed between the fixed part of the reed **2** and its base **1** and the reed is attached to the base by screws **7**, **7'** passing through the insulative bushings **8**, **8'**; thus the reed is normally electrically insulated from the base. As aforementioned the reed is metallic, and hence electrically conductive. Likewise the base **1** is metallic, of metal entirely or at least in the portion near the slot **3**. The terminals of a source of electric potential +B, −B are connected respectively to the reed **2** and the metallic part of the base **1**.

The motions of the reed as aforedescribed are periodically interrupted by the base at the vibration frequency of the reed, and coincident with these interruptions electrical contact is made between the reed **2** and the base **1**, pulses of electrical current, derived from the source +B, −B, flowing at these instants in the circuit indicated. The frequency of these pulses correspond to that of the reed; thus if the reed vibrate at 2093 c. p. s. (cycles per second)—a high C note in the equitempered musical scale based upon A=440 c. p. s.—2093 current pulses will occur per second.

These pulses are useful in conjunction with the devices of the aforementioned application No. 196,484, and they may be derived from the instant generator across the resistance R_1 in the electrical circuit therewith. Their form is illustrated in the graph of Figure 3, wherein the horizontal axis represents them and the vertical axis voltage referred positive to ground (so marked in various of the figures). This voltage is that appearing across the resistance R_1, in the absence of the condenser C_1.

I prefer to modify the peak type pulses exhibited in Figure 3 by reducing their complexity and harmonic content, for the reasons described in the application No. 196,484. Thus I place a condenser C_1 in parallel with the resistance R_1, and a resistance R_2 in series with this combination. With these insertions the form of pulsations derived across R_1 becomes as illustrated in Figure 4, wherein the axes have the same respective meanings as in Figure 3. While the oscillations exhibited in Figure 4, are of simpler character than those of Figure 3, it will be understood that they are nevertheless complex, for modification by the tone color circuits to be subsequently described, or as set forth in detail in the copending application No. 196,484.

In the Figure 5 there is shown an assembly of generators of the type above described. These are mounted in holes in a hollow windbox **9**, air being pumped from the box as indicated by the direction arrow near the hose flange **10** and entering the box from the reed generators as illustrated by the dotted direction arrows. The various reed assemblies shown may vibrate at the frequencies of a note and its octaves in a multioctave musical scale. Thus the reed illustrated at the right of the figure may correspond to a high C note=2093 c. p. s., the next reed the octave below, C=1046.5 c. p. s., and so on, the reed assembly at the left corresponding say to a low C note=32.70 (3125) c. p. s.

Associated with each of the reeds of Figure 5 is an electrical generating circuit similar to that set forth in Figure 1. These circuits may be energized in parallel from the common source +B, −B and each contains the resistances R_1, R_2. The condensers C_1, C_2 . . . C_7 therein correspond to the condenser C_1 above, and I have found it advantageous to evaluate these condensers according to the frequencies at which the reeds operate. The resistances R_1, R_2 may have respectively the same values throughout the generators. The following represent operative combinations:

+B, −B=20 volts
R_1=10,000 ohms
R_2=20,000 ohms
C_1, C_2 . . . C_7=.01, .02, . . . 0.46 mfds. respectively for 2093, 1046.5 . . . 32.70 c. p. s.

The voltages appearing across the various resistances R_1 are each of the form indicated by Figure 4 and their frequencies correspond to their respective reeds. Attached to ends remote from ground of the resistances R_1 are the tone productive leads "C"**1**, "C"**2** . . . "C"**7**. These may terminate in switches closable upon the depression of playing keys, and connections may be established from the switches to various tone modifying and sound reproducing apparatus, to return again to ground. In this respect, I prefer to operate my reeds continuously during the operation of a musical instrument, employing their electrical outputs thrcugh keyboard switches according to the requirements of a musical composition. By this means I dispense with the use of key operated air valves in a musical instrument, and secure prompt response at the keys.

It will be understood that an electrical musical instrument employing the generators of the type herein described may include twelve assemblies such as shown in Figure 5 to provide all the notes of a multi-register musical scale; and I have found it particularly advantageous to provide an individual windbox (**9**) per octavely related group of reeds. For I find that under this condition the reeds have a tendency to lock in frequency, by aerodynamic coupling, and by tuning the reeds to within four or five cycles of exact octave relationship, they "pull in" to exact octaves and the same phase. This exact octave, in-phase operation is accordingly translated to the electric pulsations derived from the reeds, and will hereinafter be shown to be important, as set forth in the application No. 196,484.

Thus I now have particular sources of electric oscillations for the several notes of the musical scale within the desired range of a musical instrument; and the following description relates to the means whereby the several notes may be selected in playing a desired musical composition,

whereby the oscillations for these notes may be brought to certain collecting networks for subsequent combination and modification, whereby the oscillations may be modified to provide musical tones of various qualities, and whereby output oscillations may be amplified and converted into sound. As these means have been adequately described in the copending application No. 196,484 they require only a brief description in the present specification. Since the electric oscillations in this as in the application No. 196,484 are of sufficient complexity, their modification does not require devices for increasing their complexity. Thus, means such as asymmetric electrical devices or the like need not be used and therefore the tone timbre systems employed are of essential linear character, providing advantages of economy and the simultaneous transmission of oscillations of various tone pitches without the creation of oscillations of extraneous frequencies.

In he present musical instrument or plurality of keyboards, manual and/or pedal, may be operated from the single bank of generators aforesaid, and a keyboard system is shown in Figure 6. This figure should be taken in conjunction with Figure 5 and I have similarly marked in Figure 6 the leads "C"1 . . . "C"7 from the generators of Figure 5. I have endeavored to indicate the connections for a complete keyboard and have merely indicated by appropriate spacings and dashed lines the inclusion of notes not explicitly shown. The connections for other keyboards may be similar to Figure 6 and I have indicated leads (so marked) to other keyboards. The use of a plurality of keyboards is advantageous in an instrument of the organ type, to which the present invention is particularly applicable in simulating a pipe organ.

It will be seen that the lead from each generator has branches to several keyboards where desired, and also that it has at least two branches with respect to a keyboard. Tracing for example the lead "C"1, it will be seen that it has branches 11 and 12 to other keyboards and a branch 13 to the keyboard of the figure. This in turn is divided as at 14 and 15 to different keys upon the same keyboard.

As illustrated I employ to each key of a keyboard a pair of switches, one switch being connected to the generator of the frequency which is fundamental to the note of the key and the other switch being connected to the generator delivering pulsations of the frequency an octave above. (In this statement I may except the keys of the highest octave.) Thus I may provide at a keyboard oscillations of eight foot and four foot pitch, so called in the terminology of organists. The closing of a switch by the depression of its playing key connects the corresponding oscillation source with respect to subsequent circuits. Ordinarily this would produce an electrical transient click at the beginning and end of a played note. However, I use for my key switches the mechanism illustrated and described in a copending United States patent application Serial No. 222,677 filed August 2, 1938, by John F. Jordan and myself for Electrical contacts (continuation-in-part of our application Serial No. 78,440 filed May 7, 1936). Each switch of this mechanism, which for key switches is a gang switch arrangement, is of the gradual contact type and serves adequately to provide a noisely tonal attack and decay. I have not indicated the actual playing keys in Figure 6, since these are completely shown in conjunction with the key switches in the aforementioned application No. 222,677, or means for their operation with switches will readily occur to those skilled in the art.

Each of the playing key switches includes a resistance R_3 in series with it. The purpose of these resistances is to issue a proper and adequate flow of current through each branch circuit from a generator and a more complete description of their functions is given in the copending application No. 196,484. When the resistances R_1 are each given the above mentioned value of 10,000 ohms and when the effective impedance of the immediate output device—a collecting network or header to be presently described—is of the order of 5,000 ohms, a suitable value for each resistance R_3 is 25,000 ohms.

I have shown for each pair of switches in Figure 6 a dashed line to indicate that the two switches are operated simultaneously by the corresponding key (the means for accomplishing this has been described in the aforementioned application No. 222,677). Taking one of the switch pairs such as the fourth from the left hand side in Figure 6 it will be noted that it has a switch S_k connected to the tone production lead "C"2 from the generator delivering fundamental pitch and a switch.

$$S'_k$$

connected to the branch 15 of the lead "C"1 from the generator delivering the pitch an octave above. These switches

$$S_k \text{ and } S'_k$$

are also connected respectively to collecting networks or headers *8ft* and *4ft*. Thus on depressing the corresponding key the generator fundamental to the note of a key is connected to the headers *8ft* and the generator an octave above to the headers *4ft*. Similar arrangements are provided for all keys and thus in the playing of a musical composition oscillations corresponding to the notes of the composition appear in the respective headers in octave relation. These octavely related pitches may be eight foot and four foot as aforedescribed, and it will be understood to be within the scope of my invention to provide oscillations at sixteen foot pitch, two foot pitch, and so on.

In the copending application No. 196,484 the function of the collecting networks or headers *4ft*, *8ft* has been adequately described, and for purposes of the present description it may be said briefly that they compensate for the attenuating effect of tone timbre systems. The tone timbre systems I employ in an organlike musical instrument have a combined or over-all tendency to attenuate higher frequency oscillations, and to compensate for this an extended type of resistive header is provided, which causes oscillations from lower frequency generators to pass progressively through more resistance in this collector than those of higher frequency, before reaching a tone timbre system, thus compensating for the differential attenuating tendency of the tone color systems.

I will now describe a tone timbre system for use in connection with one keyboard of the musical instrument. This is shown in Figure 7, an illustration completely described in the application No. 196,484. Figure 7 should be taken in conjunction with Figure 6 and shows a continuation of the header leads 16 and 17 therefrom. In these leads I have inserted respectively the isolating

condensers C_8 and C_9, these condensers serving to isolate the direct current components in the pulsations produced above and permitting the passage of the desired alternating current components.

I have illustrated in Figure 7 a combination of stops (so called in the terminology of organists) for a single keyboard of an organ type musical instrument. This tone color system has been set forth in detail in the application No. 196,484 and comprises a pluraiity of tone color branches or paths from the keyboard system to the output system of this instrument. These paths, of linear character, comprise various combinations of resistance, inductance, and capacity and provide various qualities of tones. They are marked as shown Oboe 8', Clarinet 8', etc. Each of them contains its respective stop switch S_{ts}, which may be of the type described in the aforementioned application No. 222,677.

Also in Figure 7 I have shown an outphasing device 18 which has been likewise adequately described in the application No. 196,484. This device is constructed in accordance with the spirit of my copending United States patent application, Serial No. 78,685, filed May 8, 1936 for Harmonic tone production, Patent No. 2,148,478 issued February 28, 1939, and provides a third header lead 19 in which oscillations appear of the pitch of those in the lead 16, but in which there is an absence or substantial diminution of the even order harmonics. The timbre of these oscillations comprising essentially the odd order harmonics is expressive of wood wind orchestral instruments and of stopped organ pipes. They are useful as such as well as in combinations with other oscillations to produce various tone timbres, and in this respect it will be noted that the header leads 16, 17, and 19 are combined in various ways in the tone color system of Figure 7.

Figure 8 illustrates an output system of the instrument and the output lead 20 from the timbre system of Figure 7 is continued into Figure 8 along with the leads 21 and 22 from other timbre systems and keyboards which may be comprised in the embodiment. The leads 20, 21, and 22 are combined to a common lead 23, directed to the initial grid circuit of a head amplifier 24, the output of this amplifier passing into a step-down transformer 25 and thence into a low impedance line containing a constant impedance type volume control 26, which may be pedal operated. The output from the control 26 passes into the main amplifier (so marked) and thence into a sound reproducer, the loudspeaker L. S. The plate supply +B' for the outphasing device 18 may be derived from the rectified current provided in and for the main amplifier; and likewise the source of potential +B, −B for the reed generators above described may be obtained conveniently from the same amplifier.

Thus I have described a particular generator of complex electric oscillations in conjunction with an electrical musical instrument. This generator includes mechanical means for its operation and modifications of it may be provided. One such modification is shown in Figures 9 and 10, wherein a free reed 27 is caused to vibrate from a jet of air directed toward its free end from a suitable nozzle or tuyère 28. The reed vibrates across the snout of the tuyère, by Bernoulli's principle it is believed, and the motions of the reed are interrupted at its frequency of vibration by a metal extension 29 attached to the tuyère. The electrical arrangements shown in conjunction with the form of generator aforedescribed as in Figures 1 and 2, are reproduced in this modification of Figures 9 and 10. The fixed end of the reed of this modification may be supported by a stationary base 30.

The second modification of the generator is shown in Figures 11 and 12. Here the open end of a metal pipe 31 is placed broadside a free reed 32, and the reed is vibrated by a suction of air maintained in the pipe, the motions of the reed being interrupted by the pipe end. A suitable base 33 is supplied for the fixed end of the reed and the foregoing electrical circuit in conjunction with the generator is reproduced in this arrangement.

It is desirable that means be provided for imparting a tremolo to the musical tones generated in an instrument such as set forth, and for such means I have found it advantageous to interrupt the main fluid stream at a subaudio rate, say at six cycles per second. For, the vibration frequencies of the reeds described are somewhat sensitive to fluid pressure variations, and thus the above mentioned interruptions of the fluid stream provides a frequency type tremolo—in my opinion this kind of tremolo is preferable to an amplitude tremolo.

Thus I have shown a particular kind of electric oscillation generator suitable as sources of complex oscillations and operated in conjunction with the tone color systems of the copending application No. 196,484. This generator is primarily of mechanical means and derives its electrical pulsations from the motions of a mechanical vibrator maintained in operation by a fluid, preferably air. Modifications may be made in the invention, and having thus described it, I claim:

1. An electric pulsation generator for an electrical musical instrument, comprising a hollow metallic reed base, a metallic vibratile reed attached to said base in juxtaposition thereto, the means for attaching said reed including electrically insulating means, said base containing a slot adjacent said reed, of lesser area than said reed, air propulsion means communicating with said base whereby air is propelled through said slot causing said reed to vibrate, said air means being of sufficient strength to cause said reed to make contact with said base periodically at the inherent frequency of vibration of said reed as so operated, a source of electric potential, and electrical connections respectively from the terminals of said source to said reed and to said base, whereby complex electric pulses are produced at said inherent frequency, and means for deriving said complex electric pulses for musical tone production.

2. An electric pulsation generator for an electrical musical instrument, comprising an electrical conductor, an electrically conductive vibratile member so supported adjacent said conductor as to make periodic contacts therewith when vibrated to the proper extent and susceptible of being vibrated to said extent directly by a fluid blast, at its inherent frequency as so vibrated, means providing a fluid blast for so vibrating said member, a source of electric potential, and electrical connections respectively from the terminals of said source to said conductor and said member, whereby complex electric pulses are produced at said inherent frequency, and means for deriving said complex electric pulses for musical tone production.

3. Apparatus as set forth in claim 2, wherein said electrically conductive vibratile member comprises a vibratile metallic reed.

4. An electric pulsation generator for an electrical musical instrument, comprising a hollow member presenting a surface suitable for electrical contact and having an orifice in said surface communicating with the interior of said member, a metallic vibratile reed so supported adjacent said member as to make periodic contacts with said surface when vibrated to the proper extent and to be susceptible of being vibrated to said extent directly by a fluid blast through said orifice, at its inherent frequency as so vibrated, means for maintaining a differential fluid pressure between the interior and exterior of said member of such an amount as to provide a fluid blast through said orifice for so vibrating said reed, a source of electric potential, and electrical connections respectively from the terminals of said source to said reed and said surface of said member, whereby complex electric pulses are produced at said inherent frequency, and means for deriving said complex electric pulses for musical tone production.

5. As an electrical impulse generator for use in an electrical musical instrument, a beating reed device comprising an apertured metallic base, a metallic reed mounted at one end upon said base adjacent said aperture so as to be vibrated by a blast of fluid passing through said aperture, said reed being insulated at its mounting end from said base, and of such size as to strike said base so as to make periodic electrical contacts therewith upon being caused to vibrate by said blast, at its inherent frequency as so operated, and a source of electric potential connected to said base and said reed.

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