March 21, 1939. P. H. FROHMAN 2,151,021

ELECTRIC ORGAN

Filed Nov. 20, 1936 3 Sheets-Sheet 1

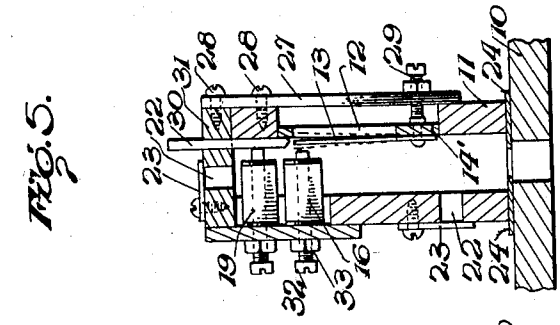


Fig. 5.

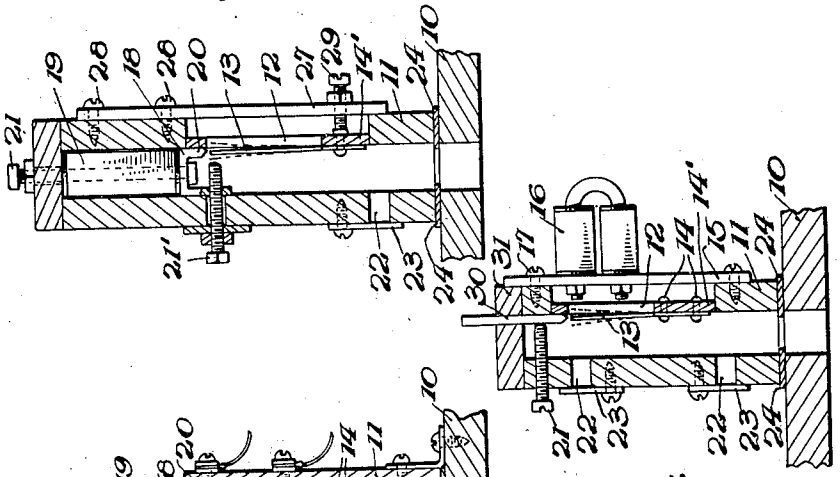


Fig. 3.

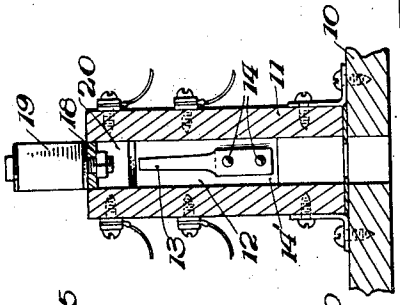


Fig. 2.

Fig. 4.

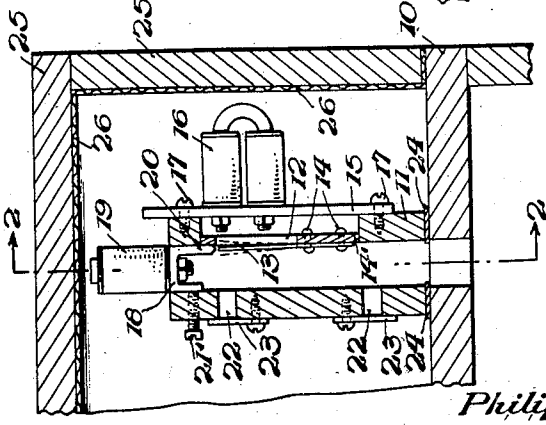


Fig. 1.

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ELECTRIC ORGAN

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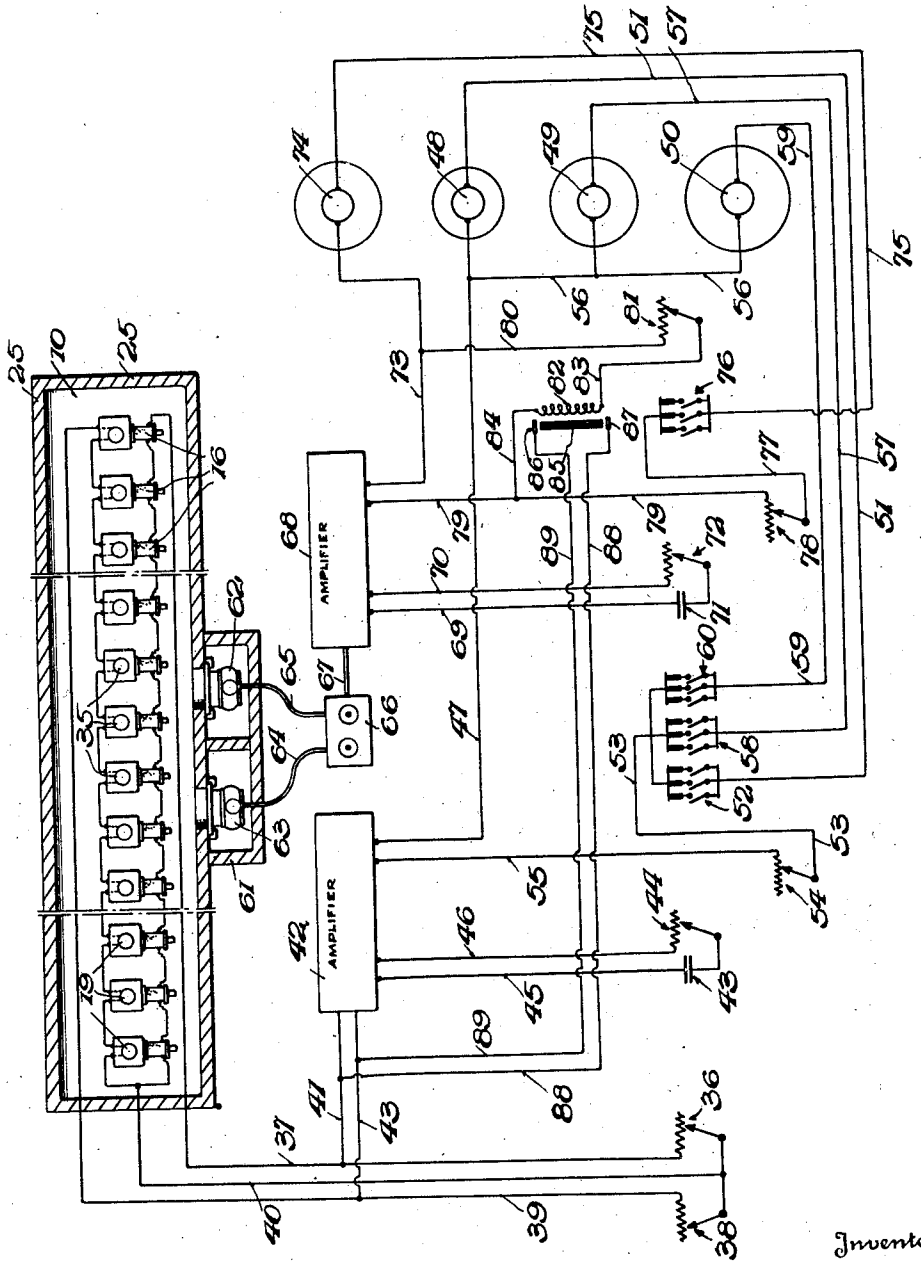


Fig. 6.

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ELECTRIC ORGAN

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Fig. 7.

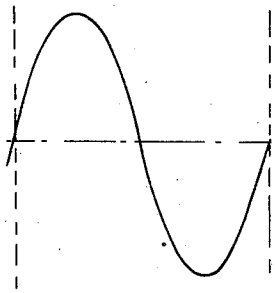


Fig. 8.

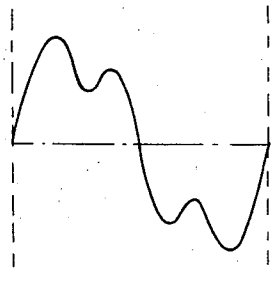


Fig. 9.

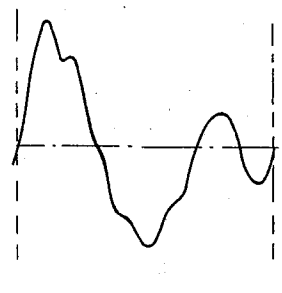


Fig. 10.

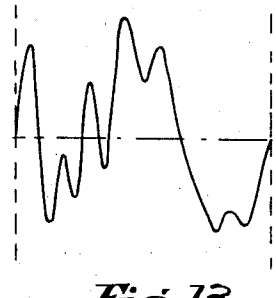


Fig. 11.

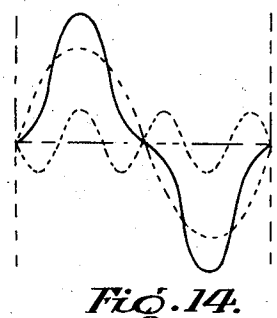


Fig. 12.

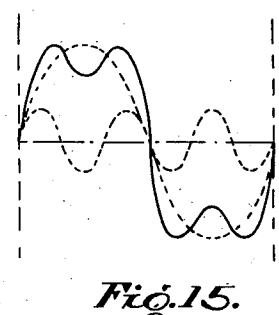


Fig. 13.

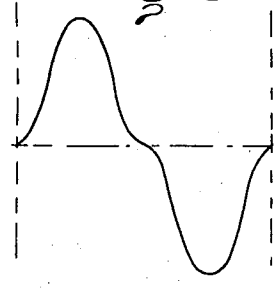


Fig. 14.

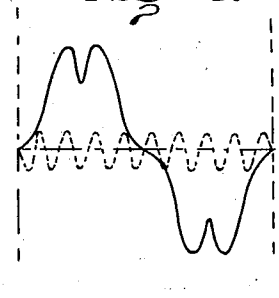


Fig. 15.

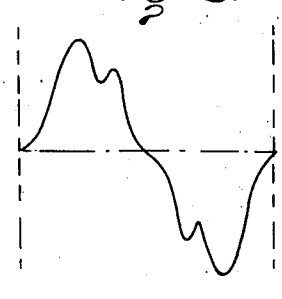


Fig. 16.

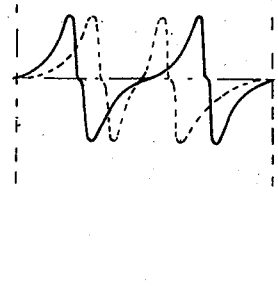
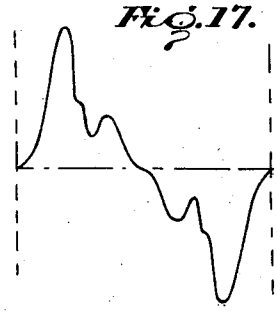


Fig. 17.



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Patented Mar. 21, 1939

2,151,021

UNITED STATES PATENT OFFICE

2,151,021

ELECTRIC ORGAN

Philip Hubert Frohman, Washington, D. C., assignor of one-half to Roland L. Taylor, Philadelphia, Pa.

Application November 20, 1936, Serial No. 111,916

43 Claims. (Cl. 84—1)

This invention relates to electrical musical instruments and more particularly to musical instruments in which a steel reed is utilized to produce electrical oscillations or alternating currents of frequencies and wave formations corresponding to the sound waves produced by organ pipes. Even more particularly this invention relates to an electrical system for translating electrical currents established by a steel reed into audible sounds closely analogous to those produced by organ pipes.

I have found that there are certain fundamental truths that control the production of musical tones by electric oscillations. First and primary among these is that an electrical oscillation to produce a musical tone should be produced by unrestrained pendular vibrations; further that a compound electrical oscillation results in a more pleasing and natural quality of musical tone if the oscillations of higher frequencies resulting in harmonics are produced by subsidiary vibrations having a natural harmonic relation to the fundamental pendular vibration rather than if the frequencies are mechanically produced and mechanically superimposed one on the other. I have also found that almost all varieties of organ tones, except reed tones, can be obtained by varying the relation of the fundamental tone and the harmonics of an open diapason pipe.

A further controlling law in the production of musical tones by the vibration of steel reeds I have found to be that the reed produces its characteristic reedy of cutting character of tone not by the production of fundamental and subsidiary vibrations in the reed itself but by the vibrations set up in the medium surrounding the reed as the sharp edges of the reed cut through this medium. Thus a reed when properly voiced may, by the elimination of the vibrations set up in the medium surrounding the reed, be made to produce approximately the same vibrations as a metal open diapason pipe with a resulting organ-like tone.

I have further found that the electrical wave set up in an electromagnetic pickup may be totally different from the sound wave of the reed and may only correspond therewith in the fundamental frequency and that it is possible by proper control of the electromagnetic pickup to obtain a wave that corresponds to the fundamental frequency alone, with the octave alone, or with other harmonics of the fundamental frequency as desired. Thus if a reed be voiced to produce a diapason quality of tone and if it is vibrated it is possible to obtain by an appropriate electromagnetic pickup electrical waves corresponding to the tones of the diapason. Further, these electrical waves may be modified by control of the electromagnetic pickup to give a wave that will produce a tone of a flute quality or if desired a compound tone similar to that of a string tone and harmonics thereof. Thus it will be at once apparent that given a desired pure tone and its harmonics induced in the electromagnetic pickup as an electric current, it is possible to obtain an infinite variety of wave formations by amplification of this current and by control thereof through a condenser of variable capacity. It is therefore possible by amplification and capacity control to obtain a perfect tone control of the vibrations set up in the reed. Using a tone control of this sort it is therefore possible with a proper electromagnetic pickup and loud speakers to obtain from tone generators composed of vibrating reeds musical sounds corresponding to the wood flute, metal open diapason, string and harmonic stops characteristic of a pipe organ of any desired amplitude of sound.

I have further found that a loud musical tone which is produced or terminated abruptly is trying to the ear and that any electrically produced musical tone will have this undesired abruptness if instituted and terminated by make and break key contacts. Consequently, electrically produced musical tones must have their production and termination retarded by physical mass and inertia to a degree commensurate with the generation and termination of sounds produced by pipes or reeds.

It is accordingly an object of my invention to provide an electrical tone generator which is more simple and more versatile than the various forms of rotors, tone wheels, tuning forks, vibrators, vacuum tube oscillators and the like heretofore proposed.

Another object of my invention is to provide an electrical tone generator that will give a pure fundamental frequency and its harmonics and which may be used in place of the pipes of a pipe organ.

A further object of my invention is to provide an electrical tone generator which creates sufficient voltage to permit all the tone generators necessary for five or more octaves of an organ manual to be connected in series, in parallel, or in series-parallel without using key contacts.

Another and still further object of my invention is to provide an electrical tone generator

which does not produce or terminate the musical note abruptly.

A still further object of my invention is to provide an electrical tone generator which responds to an acceleration or deceleration in amplitude of the sound produced in a manner similar to an organ pipe, reed, or other wind instrument.

A further object of this invention is to provide an electrical tone generator which produces alternating currents in an electromagnetic pickup by unrestrained pendular vibration.

A further object of this invention is to provide an electrical tone generator which will produce from a vibrating reed fundamental tones of the purity and roundness of flute tones of an organ without any of the characteristics of the reed tones.

A further object of this invention is to provide an electrical tone generator utilizing a vibrating reed to produce a fundamental vibration which will simultaneously and selectively produce electrical oscillations of higher frequencies resulting in tones characteristic of the open diapason, string, four foot stops, and mixtures of a pipe organ.

A further object of this invention is to provide an electrical tone generator which beside producing electrical oscillations corresponding in wave formation to the tones characteristic of organ pipe tones, will also produce reed tones similar to the reed stops and harmonic stops of a pipe organ.

A further object of this invention is to provide an electrical tone generator which will, if one is used for each note, provide means for obtaining all the individual tone qualities and combinations of tone qualities as well as a full ensemble of any desired volume characteristic of a full toned well balanced pipe organ.

A further object of this invention is to provide a simplified and novel electromagnetic pickup and sound production system for use with my novel tone generator.

It is a further object of this invention to provide a tone generator whose tone can be controlled by varying the capacity of a condenser.

Other and further objects of my invention will appear as the description of my invention proceeds.

This invention is capable of many mechanical embodiments and uses and though the accompanying drawings and description thereof disclose the invention as applied to an electrical organ it is to be expressly understood that this description and disclosure in no way limits the scope of the present invention and that to determine the scope of this invention reference should be had to the appended claims.

In the accompanying drawings:

Fig. 1 is a sectional elevation through one embodiment of my tone generator showing the relative positions of the various parts and the location of the tone generator on the wind chest with the surrounding soundproof cover;

Fig. 2 is a sectional elevation of the embodiment of the invention shown in Fig. 1 taken on the line 2—2;

Fig. 3 is a sectional elevation of another embodiment of my novel tone generator;

Fig. 4 is a sectional elevation of another embodiment of my novel tone generator;

Fig. 5 is a sectional elevation of another embodiment of my novel tone generator;

Fig. 6 is a one manual circuit diagram of one embodiment of my novel electromagnetic pickup and sound production system utilizing tone generators of the type shown in Figs. 1 and 2;

Fig 7 is a sine curve representing a simple sound;

Figs. 8 and 9 are curves representing typical sound waves of organ pipes;

Fig. 10 is a curve representing a sound wave produced by a reed tone;

Figs. 11 and 12 are curves showing a typical fundamental sound wave with the third marmonic; and

Figs. 13, 14, 15, 16 and 17 are voltage curves of currents induced in the electromagnetic pickup by my novel tone generator.

With reference now to Figs. 1–5 in which like reference characters indicate like parts throughout the several views and more particularly with reference to Figs. 1 and 2, 10 represents the top board of an organ chest of any desired make or size as may now be found on the market, it being expressly understood that the organ chest, organ key action, valve action, console and the like form no part of the present invention and that any suitable type may be used. Mounted on top board 10 are small pipe members 11, one for each note of the manual, which may be constructed of wood or other suitable material and which may vary in height from three to five inches and from one to one and one-quarter inches in diameter depending on the note it is to reproduce. Mounted in an opening 12 in pipe 11 is a magnetized reed 13 of steel or other suitable material fixed to a non-magnetic metal plate 14' by rivets 14 or by other suitable means to allow reed 13 to vibrate in a free pendular vibration, plate 14' being fixed to pipe 11 by any suitable means. Mounted opposite opening 12 in pipe 11 and carried by a non-magnetic bracket 15 is a field coil 16 having a soft iron core and wound to afford an impedance sufficient to give a sufficient voltage at the given frequency of the reed 13. Bracket 15 is fixed to pipe 11 by screws 17 which engage slots in bracket 15 and affords a means for adjusting coil 16 with reference to the tip of reed 13 and thereby adjusting the voltage induced in coil 16. Closing the top of pipe 11 is pole piece 18 of field coil 19. Pole piece 18 has a sharp end 20 adjacent the tip of reed 13. The air gap between end 20 of pole piece 18 and the tip of reed 13 may be varied by sliding coil 19 and pole piece 18 into or out of pipe 11, a set screw 21 being provided to engage pole piece 18 and lock it in any desired position. Bored through pipe 11 are holes 22 covered by adjustable caps 23 and designed to regulate air pressures and to break up periodic vibrations in the air column in pipe 11. Arranged between pipe 11 and top board 10 are any suitable means such as adjustable plates 24 for varying the area of the opening of the pipe in the wind chest. Arranged around the set of generators mounted on the top board 10 of the wind chest of the organ is a sound box 25 lined with sound absorbent material 26 to render the sounds of the reed inaudible.

In the embodiment of the novel tone generator shown in Fig. 3, a permanent bar magnet 27 is fixed to pipe 11 by screws 28 and is in magnetic engagement with reed 13 through clamp bolt 29 to give reed 13 a heavier magnetization. In this embodiment one field coil 19 is used and is fixed in position closing the end of pipe 11. Adjustment of the voltage induced in coil 19 by the vibration of reed 13 is had by varying the position of pole piece 18 and edge 20 with reference

to the tip of reed 13. Set screw 21 provides the necessary adjusting means. Set screw 21' is the pole piece of the coil 19 in which is induced the fundamental frequency. By change of position of screw 21' the voltage of the fundamental may be varied.

In the embodiment of the novel tone generator shown in Fig. 4, the field coil 19 and its pole piece 18 are dispensed with and in its place a soft iron bar 30 is used which slides in an appropriate slot provided in cap member 31 which closes pipe 11. A suitable set screw 21 acts to hold bar 30 in place after adjustment with reference to the tip of reed 13.

In the embodiment of my novel tone generator shown in Fig. 5, the pipe 11 is closed by a cap member 31 which carries a soft iron bar 30. Mounted opposite bar 30 and carried by pipe 11 is field coil 19 designed to engage bar 30 and hold it in place after adjustment of bar 30 with reference to the tip of reed 13. Adjacent field coil 19 and carried by pipe 11 is field coil 16 provided with any suitable means such as bolt 32 and nut 33 for adjustment of its position with reference to the tip of reed 13.

Reeds 13 are of fine quality magnetic spring steel or other suitable material. The reeds 13 are tuned to give the required frequency and pitch and are proportioned and voiced to give a full diapason-like quality when vibrated without wind and to give a reed tone rich in harmonics when blown by air. Reeds 13 are magnetized and are therefore when vibrated a vibrating magnetic armature. It has been found that better results are obtained when the shorter high treble reeds are of the same length as those of lower register to provide the mass of metal necessary for the desired amount of magnetic flux. This is accomplished by giving the stationary heel of the reed such a length as to give the overall length required. Additional magnetic flux may be given reed 13 by the use of permanent bar magnets as shown above with reference to Figs. 3 and 5.

Fig. 6 shows a novel circuit diagram of an electromagnetic pickup and sound production system for one manual of an organ utilizing tone generators of the embodiment of the invention shown in Figs. 1 and 2. As in those figures, 10 represents the top board of an organ chest. Mounted on top board 10 are the tone generators generally indicated at 35. There is one tone generator 35 for each note of the manual. Surrounding tone generators 35 is a soundproof cover 25. Field coils 16 of tone generators 35 are connected in series and are electrically connected to a variable resistance 36 by an electrical conduit 37. Field coils 19 of tone generators 35 are connected in series and are electrically connected to a variable resistance 38 by an electrical conduit 39. Field coils 16 and 19 have a common electrical conduit 40 leading to the variable resistances 36 and 38 which may be mounted on the console of the organ. Resistances 36 and 38 are utilized to cut out field coils 16 or 19 as desired or to vary the current from each as may be desired. From conduit 37 a take-off 41 is led to one side of an amplifier 42 of any suitable construction and supplied with current in any suitable way. A take-off 43 joins conduit 39 and the other side of amplifier 42. Located at the console of the organ is a condenser 43 and a variable resistance 44 connected to amplifier 42 by conduits 45 and 46 to afford a tone control for the amplifier. From amplifier 42 a conduit 47 leads to three loud speakers 48, 49 and 50 connected in parallel and responsive to different ranges of frequencies. For instance, speaker 48 may be responsive to frequencies from 2,000 to 16,000 vibrations per second, that is, the string tones and upper harmonics; speaker 49 may have a moderate frequency response to provide the diapason tone; and speaker 50 may have a low frequency response to provide the flute stops. From the other side of speaker 48 a conduit 51 leads to a variable resistance 52 located on the console and controlled by a stop or series of stops to give varying degrees of loudness. From resistance 52 a conduit 53 leads to a variable resistance 54 common to speakers 48, 49 and 50 which controls the loudness of the tone of these speakers as a unit and is operated by the swell pedal at the console. From resistance 54 the circuit is completed to amplifier 42 by conduit 55. Speaker 49 is connected in parallel with speaker 48 by conduit 56. From the other side of speaker 49 a conduit 57 leads to a variable resistance 58 similar to resistance 52 and for the same purposes. From resistance 58 the circuit is completed through conduit 53, resistance 54 and conduit 55 to amplifier 42. Speaker 50 is connected in parallel with speakers 48 and 49 by conduit 56. From the other side of speaker 50 a conduit 59 leads to a variable resistance 60 similar to resistances 52 and 58 and for the same purposes. From resistance 60 the circuit is completed through conduit 53, resistance 54 and conduit 55 to amplifier 42.

Secured to cover 25 is soundproof box 61. Within box 61 are arranged microphones 62 and 63 opening into the interior of cover 25 and so constructed as to pick up the vibrations caused by the reeds in the surrounding air from which are produced the reed tones as above described. Conduits 64 and 65 lead to a two-position electronic mixer 66. Electronic mixer 66 is connected to amplifier 68 of any suitable construction and supplied with current by any suitable means by conduit 67 and affords a means for varying the input to amplifier 68 to give mixtures of two distinct qualities of reed tones. From amplifier 68 conduits 69 and 70 lead to a condenser 71 and variable resistance 72 mounted on the console to afford a tone control for amplifier 68 for varying the degrees of harmonic reed tone. From amplifier 68 a conduit 73 leads to a loud speaker 74 which will react to frequencies within a range of frequencies containing the reed tones. From speaker 74 a conduit 75 leads to a variable resistance 76 located at the console to control the voltage to speaker 74 and provide loud and soft reed stops. From resistance 76 a conduit 77 leads to a variable resistance 78 operated by the swell pedal at the console to afford a master control for the reed stops. From resistance 78 the circuit is completed to amplifier 68 by conduit 79.

From conduit 73 a conduit 80 leads to a variable resistance 81. Resistance 81 is connected to an induction coil 82 by a conduit 83. This circuit is completed by conduit 84 leading from induction coil 82 to conduit 79. Induction coil 82 has a soft iron core 85. Adjacent core 85 are brass plates 86 and 87. Plate 86 is connected by conduit 89 to conduit 43. Plate 87 is connected by conduit 88 with conduit 41. Reed tone frequencies from amplifier 68 of voltage controlled by resistance 81 induce into core 85 and plates 86 and 87 the highest of these reed tone frequencies. These highest frequencies then pass to conduits 41 and 43 where they combine with the

frequencies supplied by the tone generators 35 to enrich these frequencies to give a sound similar to adding a mixture stop to the tones produced by speakers 48, 49 and 50 in addition to and independent of the reed tones given by speaker 74.

Now suppose that the circuit is set up as in Fig. 6 and that the wind chest of the organ contains air under pressure. When a key on the manual is depressed, air under pressure is admitted to the tone generator 35 corresponding to the key depressed and the corresponding reed 13 is vibrated at the frequency for which it is tuned. As reed 13 is magnetized it will set up in the adjacent field coils an induced current. In coil 16 the frequency of this induced current will be the frequency of the reed. In coil 19 the frequency of the current induced will be twice the frequency of the reed as the tip of reed 13 passes the sharp end 20 of pole piece 18 twice for each cycle of pendular movement of the reed.

The pendular movement of reed 13 corresponds to the sine curve shown in Fig. 7. At the beginning of the stroke of reed 13 the voltage induced in coil 16 is zero. This voltage increases with the increase in acceleration of reed 13 as it approaches coil 16, reaches a peak at the center of its stroke when the velocity is the greatest and then decreases with the deceleration at the opposite end of the stroke and becomes zero as reed 13 comes to rest, and then reverses generating a negative voltage equal and opposite to the voltage induced in the first part of the cycle. As there is no instant reversal of the flow of current and reed 13 comes to rest before the flow reverses there is an acceleration and deceleration curve at the end of each stroke. Therefore the electrical wave induced in coil 16 is represented by Fig. 13 rather than by Fig. 7. Fig. 13 is approximately the same as Fig. 11 which shows the curve of simple fundamental tone and the third harmonic having phase relations and amplitudes as shown by the dotted lines. Theoretically then if this induced current in coil 16 be translated into sound a musical tone having a strong fundamental and audible third harmonic should result. Actually, however, it is found that this tone may vary from a pure flute tone of Fig. 7 to a diapason tone of Fig. 8 with second and third harmonics depending on the setting of the tone control of the amplifier. When a loud speaker with a frequency response of 2,000–16,000 vibrations per second is used the fundamental is less predominant and the third harmonic strong with a resulting tone of a diapason of string quality such as a violin diapason or viola. The tone is enriched by the presence of subsidiary vibrations in the reed of small amplitude and high frequency. These frequencies correspond to the natural harmonics of the fundamental and become audible with the tone control off. These frequencies correspond to those of a metal open diapason pipe as the reeds are chosen to this end, and the tone produced is that of a well voiced open diapason. With a loud speaker of moderate frequency response the tone is more that of a horn diapason of fine quality. As the tone control is turned on this tone changes to a beautiful French horn quality and finally to a tone similar to an orchestral flute or melodia stop of a pipe organ. With a speaker of low frequency response and proper tone control this tone may be reduced to a simple tone of a stopped diapason or gedeckt.

The position and shape of the pole piece 18 of coil 19 alone has a marked effect on the current produced in coil 16 and on the form of the wave produced in coil 16 with consequent change in the tone produced therefrom. At the center of each oscillation of reed 13 part of the magnetic flux flows to pole piece 18 and is not effective in coil 16 and a drop in voltage in coil 16 results. This is a sudden and brief drop in the voltage as reed 13 has its maximum velocity at this time resulting in a sharp dent in the voltage curve at its crest as seen in Fig. 14 and the resulting sound wave has the same shape. This curve is similar to that of a musical tone of strong fundamental with third and fifth harmonics. Due to the phase relations of the added harmonics the curve is similar to a combination of curves shown in Figs. 11 and 12 which are composed of fundamentals and third harmonics of different phase relations. By placing edge 20 of pole piece 18 off the center of oscillation of reed 13 the resulting induced voltage curve is similar to that shown in Fig. 15. This curve is similar to a combination of the curve of Fig. 8 of the open diapason and of a portion of the curve of Fig. 9 which was recorded from an organ pipe of a stop voiced to give a tone of string and reed like quality, known as a "reedless oboe". A comparison of the curve of an orchestral oboe as seen in Fig. 10 shows that this tone, though rich in harmonics, is smoother than a reed and does not have the weak fundamental and strong harmonics of frequencies above the eighth which distinguish reed tones.

In Fig. 14 the sharp dent shown in the crest of the curve results in a very sharp sound giving an impression of the addition of a harmonic of high frequency such as indicated by the dotted line. This dotted line indicates a frequency having the same pitch for each wave as the single wave caused by the sudden voltage drop and rise at the crests of the fundamental. Due to this pitch corresponding to a single wave of high frequency, this dent in the voltage curve may be eliminated by the reactance of the capacity of the condenser of the tone control. The tone may therefore be changed at will from the smooth round tone of Fig. 13 to the tone of Fig. 14 or 15 which is rich in harmonics. With a loud speaker of moderate frequency response, the tone varies from that of a flute to that of a diapason with a bright and harmonic tone giving the effect of adding the octave and the twelfth and fifteenth stops. With a speaker of high frequency response the tone may be varied from that of a smooth string to a brilliant and even cutting quality of tone.

Fig. 16 represents the curve of the current induced in coil 19. This is double the frequency of the fundamental as explained above and is therefore the second harmonic or octave. The peculiar form of this wave shows the sharp reversal of flow occurring as the reed approaches and passes point 20 of pole piece 18. While this sudden reversal is going on the effect is that of a current of higher frequency than the octave with a resulting sound of brilliant effect similar to a mixture stop. The reactance of the tone control can smooth out this curve as will also a speaker of low or moderate frequency response. On the other hand a speaker of high frequency response will produce a sound not only of the octave frequency but of the frequency following the sharp pitch of the crests of these waves. Thus by use of the tone control and speakers of appropriate frequency response this octave tone may vary from a smooth diapason to a tone of brilliance equal to the two foot stops and mixtures.

With a change in position of the sharp edge

20 of pole piece 18 a change in phase occurs as shown by the dotted line in Fig. 16. This gives two waves close together and two waves further apart having a cycle of these alternations within a cycle of the fundamental tone. The resulting sound wave has the effect of an eight foot tone and a four foot tone combined in which the energy of sound is about equally divided between the two. The sharp formation of these waves results in a sound similar to that of a fundamental plus a strong octave and third and fifth harmonics. Using appropriate tone control and speakers of appropriate response this tone may be varied from a rich and pleasing string quality similar to the Salicional to a sharp string similar to the Viol de Gamba.

Fig. 17 is a wave form which may be had when the currents induced in coils 16 and 19 are combined. By varying their relative voltages by means of resistances 36 and 38 located at the console the wave form may be altered to any combination of the waves shown in Figs. 7, 13, 16 and 17. The tone generator may therefore be made at will to produce fundamental tones and combinations of fundamental tones and harmonics resulting in the various qualities of flute, diapson, and string tone characteristics of a pipe organ.

It was stated above that the reed quality of tone produced by a vibrating reed was due not to vibrations set up in the body of the vibrating reed itself but was due to the vibrations set up in the surrounding air by the sharp edges of the reed cutting through the air as the reed vibrated. It has been found that the most simple and effective way to pick up these tones is by a direct microphonic pickup. To this end microphones of any desired construction and characteristics are placed in a soundproof box with access to the interior of the soundproof box surrounding the tone generators. The harmonic structure of the oscillating current produced by the microphones may be varied to a marked degree by the material of which the box surrounding them is constructed and by the size of the opening. If the enclosure of the microphones is of a non-resonant sound absorbing material and the opening is small or closed, certain harmonics of high frequency are absorbed or their energy greatly reduced while the fundamental frequency predominates which when amplified and produced by a speaker gives a very smooth quality of reed tone with a strong fundamental resembling a clarinet and flute combined. By appropriate tone control, as above described, and by the selective use of speakers of different ranges of frequency response this tone may be varied still further. If the microphones are placed within a metal box and a large opening is used the higher frequency vibrations are trapped by the microphones and after amplification and production by a speaker of suitable response will give reed tones up to those of a sharp and cutting character. By use of this microphonic pickup and proper tone control as well as suitable choice of material for the microphone box the reed tones of the tone generators may be varied from that of a soft oboe to that of a trumpet or tuba giving the smallest organ the full brilliance of the loudest reed stops to be found in a pipe organ.

While the operation of the present invention has been described with reference to the embodiment of my novel tone generator employing two field coils, it will be immediately apparent to those skilled in the art that virtually the same modification of the induced voltage curve will be had when a bar of magnetic material is substituted for coil 19 as in Fig. 4 or when one field coil is used to do the work of both coils 16 and 19 as in Fig. 3. By use of the bar of magnetic material as in Fig. 4 much of the magnetic flux generated by reed 13 when it is vibrated is absorbed as reed 13 passes the bar of magnetic material. Therefore less magnetic flux is available to induce voltages in coil 16 and a sharp drop at the peak of the voltage curve results as explained above with reference to the embodiment of the tone generator having two field coils and with analogous results. In this embodiment there is but one circuit from the tone generators 35 to the amplifier 42 and one of the resistances 36 and 38 is not used. When one coil is used in place of coils 16 and 19 as in Fig. 3 the same results are had. As reed 13 passes sharp edge 20 of pole piece 18 a greater part of the magnetic flux is absorbed by this portion of pole piece 18 and the flux surrounding the balance of the pole piece 18 is reduced with a consequent sharp drop in the voltage induced in the coil as described above and with analogous results. Here again but one circuit is used from the tone generators 35 to the amplifier 42 and one of the resistances 36 and 38 is not used.

In the description of my novel tone generators the pole piece 18 has been described as having a sharp edged portion 20 adjacent the tip of reed 13. A considerable and marked variation in the tone produced will be had if the shape of this portion is varied. If a round edge is used a round smooth tone is obtained while a sharper edge produces a sharper tone. This is readily understood as the shape of the edge influences the amount of magnetic flux absorbed and also influences the velocity at which the reed passes the edge with consequent influence on the shape of the drop occurring at the peak of the induced voltage curve. This is likewise true in the case of the shape of end of bar 30.

It will now be apparent to those skilled in the art that the present invention provides a novel tone generator and electromagnetic pickup and tone production system that will produce those fundamental tones and harmonics which give the various qualities of flute, diapason, and string tone characteristic of a pipe organ as well as one which will produce the quality of reed characteristic. It is further apparent that the present invention presents a simple and practical means to accomplish these ends which may be used in place of the pipes of a pipe organ and which will produce and terminate the musical notes in the same manner as a pipe of a pipe organ by the use of unrestrained pendular vibrations and which will give all the individual tone qualities and combinations of tone qualities as well as a full ensemble of any desired volume characteristic of a full toned well balanced pipe organ. It is also apparent that with the novel tone generators described by the present invention no key contacts are necessary and that the voltage induced in each coil is sufficient to perform its function without the use of additional means to assist it.

It will be further apparent to those skilled in the art that changes may be made in the above described embodiment of the present invention without departing from the inventive concept thereof. For instance the reeds may be vibrated by means of a vacuum rather than by a column of air under pressure; or the tone generators may be placed on the sides of the wind chest of the organ; or the tone generators may be arranged

in ranks on the wind chest; or the tone generators may be connected in parallel or series parallel; or the tone generators may be arranged in groups on a single channel board. It is also apparent that the several embodiments of my novel tone generator are perfectly interchangeable and may be selected for use as the circumstances require. Reference should therefore be had to the appended claims to determine the scope of the present invention.

What is claimed is:

1. In a tone generator of the type described having a wind chest and key control therefor, means for producing electrical oscillations corresponding to sound waves produced by an open diapason organ pipe comprising a plurality of reeds mounted on said chest and field coils with non-magnetized cores for each of said reeds whereby when said reeds are vibrated electrical oscillations are induced in said field coils.

2. In a tone generator of the type described having a wind chest and key control therefor, means for producing electrical oscillations corresponding to sound waves produced by an open diapason organ pipe comprising a plurality of permanently magnetized reeds mounted on said chest one for each note of the manual and field coils for each of said reeds whereby when said feeds are vibrated electrical oscillations are induced in said field coils corresponding to sound waves of an open diapason pipe.

3. In a tone generator of the type described, means for producing tones characteristic of wood and metal pipes of an organ including a plurality of permanently magnetized steel reeds, field coils for said reeds, an amplifier for said field coils, a tone control for said amplifier, and loud speakers for said amplifier whereby when said reeds are vibrated electrical oscillations are induced in said field coils which are amplified by said amplifier and controlled by said tone control to produce in said loud speakers diapason, flute, and string tones.

4. In a tone generator of the type described, means for producing tones characteristic of a pipe organ including a plurality of magnetized steel reeds, field coils for said reeds, an amplifier for said field coils, a tone control for said amplifier, loud speakers for said amplifier, microphones adjacent said reeds, an amplifier for said microphones, a tone control for said microphone amplifier, and loud speakers for said microphone amplifier whereby when said reeds are vibrated electrical oscillations are induced in said field coils which are amplified by said first named amplifier and controlled by said first named tone control to produce in said first named loud speakers diapason, flute, and string tones and said microphones pick up air vibrations caused by said reeds which are amplified by said microphone amplifier and controlled by said microphone tone control to produce reed tones in said second named speakers.

5. In a tone generator of the type described, a magnetized steel reed, a field coil adjacent said reed, a bar of magnetic material adjacent said reed, and an electromagnetic pickup and tone generation system for said coil whereby when said reed is vibrated electrical oscillations influenced by said bar are induced in said coil and translated into sound by said system.

6. In a tone generator of the type described, means for producing musical tones of flute, horn, diapason or string quality as well as harmonics of higher frequencies than the fundamental tones including a plurality of magnetized steel reeds, field coils for said reeds, a bar of magnetic material for each of said reeds adjacent said reed and said coil, and an electromagnetic pickup and tone production system for said coils whereby when said reeds are vibrated oscillating electric currents influenced by said bars are induced in said coils and reproduced as musical tones by said system.

7. In a tone generator of the type described, a tone generator for each note of the manual including a magnetized steel reed, a field coil adjacent said reed and a bar of magnetic material adjacent one end of said coil and opposite the tip of said reed whereby when said reed is vibrated an oscillating electrical current will be induced in said coil of a form influenced by said bar and different from the form induced by said reed alone and corresponding to a sound wave of strong fundamental and audible third and fifth harmonics.

8. In a tone generator of the type described, means for producing an electrical oscillation corresponding to a sound wave of strong fundamental and audible third and fifth harmonics, including a magnetized steel reed, a field coil arranged adjacent the tip of said reed, and a bar of magnetic material arranged adjacent one end of said coil and opposite the tip of said reed whereby when said reed is vibrated an electric oscillation is induced in said coil which is altered in form by said bar.

9. In a tone generator of the type described, including a magnetized steel reed and a field coil adjacent the reed, means for altering the form of the oscillating electric current induced in said coil when said reed is vibrated to correspond to a sound wave of strong fundamental and third and fifth harmonics, including a bar of magnetic material arranged adjacent one end of said coil and opposite the tip of said reed.

10. In a tone generator of the type described, including a magnetized reed and a field coil adjacent the reed, means for altering the electrical wave induced in said coil when said reed is vibrated and for causing a deflection in the voltage curve including a bar of magnetic material with a sharpened edge arranged adjacent one end of said coil and with its sharpened edge opposite the tip of said reed.

11. In a tone generator of the type described, including a magnetized reed and a field coil adjacent the reed, means for altering the electrical wave induced in said coil when said reed is vibrated and for causing a deflection in the voltage curve including a bar of magnetic material with a shaped edge arranged adjacent one end of said coil with its shaped edge opposite and spaced apart from the tip of said reed.

12. In a tone generator of the type described, a magnetized reed, a field coil adjacent the reed and means disposed adjacent one end of said coil and opposite the tip of said reed for causing a fluctuation in the voltage curve induced in said coil when said reed is vibrated to alter said voltage curve to give said voltage curve the effect of the addition of a superimposed current of the frequency of a harmonic of the fundamental tone whose curve corresponds to the unaltered voltage curve.

13. In a tone generator of the type described, a magnetized reed, a field coil adjacent the reed, and means disposed adjacent one end of said coil and opposite the tip of said reed, including a second field coil for causing a sharp indentation

in the voltage curve induced in said first named field coil when said reed is vibrated whose pitch corresponds with the wave of a harmonic of a musical tone of a frequency corresponding to the frequency of the reed.

14. In a tone generator of the type described, a magnetized reed, a field coil adjacent the reed and means on said coil and opposite the tip of said reed including a pointed projection spaced apart from the tip of said reed for causing a sharp indentation in the voltage curve induced in said coil when said reed is vibrated, whose pitch corresponds with the wave of a harmonic of a musical tone of a frequency corresponding to the frequency of the reed.

15. In a tone generator of the type described, a magnetized reed, a field coil adjacent the tip of said reed and a pole piece for said coil including a shaped projection spaced apart from and opposite the tip of said reed for causing a sharp indentation in the voltage curve induced in said coil when said reed is vibrated whose pitch corresponds with the wave of a harmonic of a musical tone of a frequency corresponding to the frequency of the reed.

16. In a tone generator of the type described, a magnetized reed, a field coil adjacent the reed and means for altering the shape of the voltage curve induced in said coil when said reed is vibrated including a bar of magnetic material having a sharp edge lying in the plane of said reed when at rest and opposite the tip of said reed and adjustable angularly with respect to the tip of said reed.

17. In a tone generator of the type described, a magnetized reed, a field coil adjacent the reed and means for altering the shape of the voltage curve induced in said coil when said reed is vibrated including a second field coil, a pole piece for said second named field coil, a shaped projection depending from said pole piece and lying apart from and in the plane of said reed when at rest and adjustable angularly with respect to the tip of said reed.

18. In a tone generator of the type described, a magnetized reed, a field coil for said reed and means for altering the shape of the voltage curve induced in said coil when said reed is vibrated including a pole piece for said coil and a projection from said pole piece having a shaped edge lying in the plane of said reed when at rest and spaced apart from the tip of said reed and adjustable angularly with respect to the tip of said reed.

19. In a tone generator of the type described having a magnetized reed and a field coil adjacent the tip of said reed, means for inducing an electrical wave in said field coil when said reed is vibrated corresponding to a sound wave of sharp tone including a member of magnetic material having a chisel shaped edge lying in the plane of the reed when at rest and spaced apart from and adjacent the tip of the reed.

20. In a tone generator of the type described having a magnetized reed and a field coil adjacent the reed, means for inducing an electrical wave in said coil when said reed is vibrated corresponding to a sound wave of round tone including a member of magnetic material having a rounded edge lying in the plane of said reed when at rest and spaced apart from and adjacent the tip of the reed.

21. In a tone generator of the type described, a magnetized reed, a field coil adjacent said reed, and means for creating a fluctuation of the voltage induced in said coil when said reed is vibrated of such rapidity as compared to the frequency of the reed as to correspond with a sound wave of high frequency including a member of magnetic material adjacent the tip of said reed.

22. In a tone generator of the type described, a magnetized reed, a field soil adjacent said reed and pole pieces for said field coil so constructed and arranged with respect to said reed that when said reed is vibrated a voltage wave will be induced in one pole piece corresponding to a fundamental musical tone of round quality and a voltage wave will be induced in the other of said pole pieces corresponding to a first harmonic of said fundamental musical tone.

23. In a tone generator of the type described, a magnetized reed, a field coil adjacent said reed, and a pole piece for said field coil so constructed and arranged with respect to said reed that when said reed is vibrated two currents of different frequencies and different wave forms will be induced simultaneously in said field coil.

24. In a tone generator of the type described, a magnetized reed and two field coils adjacent said reed so constructed and arranged with respect to said reed that when said reed is vibrated currents will be induced in said field coils having different frequencies and adjustable wave formations.

25. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and a pair of field coils, means joining said field coils in series including a pair of variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier in series, each of said speakers having a variable resistance in series therewith to control the loudness of tone of each speaker individually and a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group.

26. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and a pair of field coils, means joining said field coils in series including a pair of variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier incuding a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier in series, a variable resistance in series with each of said speakers to control the loudness of tone of each of said speakers individually, a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier incuding a condenser and a variable resistance to eliminate any desired high frequencies, a loud speaker connected in series to said amplifier, a variable resistance connected to said speaker to control the loudness of tone of said speaker, and a

second variable resistance connected to said speaker to vary the loudness of tone of said speaker in accordance with the loudness of tone of said first named group of speakers.

27. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and a pair of field coils, means joining said field coils in series including a pair of variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier incuding a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier in series, a variable resistance in series with each of said speakers to control the loudness of tone of each of said speakers individually, a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired high frequencies, a loud speaker connected in series to said amplifier, a variable resistance connected to said speaker to control the loudness of tone of said speaker, and a second variable resistance connected to said speaker to vary the loudness of tone of said speaker in accordance with the loudness of tone of said first named group of speakers, an induction coil including a metal core and a pair of plates spaced apart from and at opposite ends of said core, means including a variable resistance connecting said coil across the circuit of said last named speaker, and means connecting said plates to said field coils.

28. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and field coil, means joining said field coils in series including a variable resistance to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistance, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier in series, each of said speakers having a variable resistance in series therewith to control the loudness of tone of each speaker individually and a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group.

29. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and a field coil, means joining said field coils in series including a variable resistance to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistance, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier, a variable resistance in series with each of said speakers to control the loudness of tone of each of said speakers individually, a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired high frequencies, a loud speaker connected in series to said amplifier, a variable resistance connected to said speaker to control the loudness of tone of said speaker, and a second variable resistance connected to said speaker to vary the loudness of tone of said speaker in accordance with the loudness of tone of said first named group of speakers.

30. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and a field coil, means joining said field coils in series including a variable resistance to control the currents induced in said coil when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistance, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired higher frequencies from said currents, a plurality of loud speakers responsive to different ranges of frequencies connected in parallel and connected to said amplifier, a variable resistance in series with each of said speakers to control the loudness of tone of each of said speakers individually, a variable resistance in series with said speakers to control the loudness of tone of said speakers as a group, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier including a condenser and a variable resistance to eliminate any desired high frequencies, a loud speaker connected in series to said amplifier, a variable resistance connected to said speaker to control the loudness of tone of said speaker, and a second variable resistance connected to said speaker to vary the loudness of tone of said speaker in accordance with the loudness of tone of said first named group of speakers, an induction coil including a metal core and a pair of plates spaced apart from and at opposite ends of said core, means including a variable resistance connecting said coil across the circuit of said last named speaker, and means connecting said plates to said field coils.

31. In a tone generator of the type described, means for producing tones characteristic of a pipe organ, including a plurality of steel reeds producing musical tones both electromagnetically and audibly when vibrated, microphones adjacent said reeds, an amplifier for said microphones, a tone control for said amplifier, and loud speakers for said amplifier whereby when said reeds are vibrated said microphones pick up air vibrations caused by said reeds which are amplified by said amplifier and controlled by said tone control to produce reed tones in said speakers.

32. In an electric organ in which the fundamental tones and certain harmonics are electromagnetically produced, a plurality of tuned tone generators producing additional harmonics audibly, microphones adjacent said tone generators to pick up audible harmonic frequencies created by said tone generators, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control

for said amplifier including a condenser and a variable resistance to eliminate any desired high frequencies, a loud speaker connected in series to said amplifier, and a variable resistancce connected to said speaker to control the loudness of tone of said speaker.

33. In an electric organ in which the fundamental tones and certain harmonics are electromagnetically produced, a plurality of tuned tone generators producing additional harmonics audibly, each including a reed, microphones adjacent said reeds to pick up audible harmonic frequencies created by said reeds, an amplifier for said microphones, a tone control for said amplifier, and a loud speaker for said amplifier whereby when said reeds are vibrated said microphones pick up air vibrations caused by said reeds which are amplified by said amplifier and controlled by said tone control to produce reed tones in said speakers.

34. In an electric organ in which the fundamental tones and certain harmonics are electromagnetically produced, a plurality of tuned tone generators producing additional harmonics audibly, each including a reed, microphones adjacent said reeds to pick up audible harmonic frequencies created by said reeds, an electronic mixer for said microphones, an amplifier for said microphones, a tone control for said amplifier including a variable resistance and a condenser, and a loud speaker for said amplifier whereby when said reeds are vibrated said microphones pick up air vibrations caused by said reeds which are amplified by said amplifier and controlled by said tone control to produce reed tones in said speakers.

35. In a tone generator of the type described, a magnetized steel reed, a field coil adjacent said reed, a second field coil adjacent said reed, and an electromagnetic pickup and tone generation system for said coils whereby when said reed is vibrated differing electrical oscillations of differing frequencies are induced in said coils and translated into sound by said system producing differing tonal qualities for each of said coils.

36. In a tone generator of the type described, a magnetized steel reed, a field coil adjacent said reed and at right angles thereto, a bar of magnetic material adjacent said reed, and an electromagnetic pickup and tone generation system for said coil whereby when said reed is vibrated electrical oscillations influenced by said bar are induced in said coil and translated into sound by said system.

37. In a tone generator of the type described, a magnetized steel reed, a field coil adjacent said reed, a bar of magnetic material adjacent said reed and parallel thereto, a second field coil at right angles to said bar and in magnetic contact therewith, and an electromagnetic pickup and tone generation system for said coils whereby when said reed is vibrated electrical oscillations influenced by said bar and second named coil are induced in said first named coil and translated into sound by said system.

38. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and field coils, means joining said coils including variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier including a condenser and a variable resistance, and a plurality of loud speakers connected to said amplifier.

39. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and field coils, means joining said coils including variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier including a condenser and a variable resistance, a plurality of loud speakers connected to said amplifier, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier including a condenser and variable resistance, and a loud speaker for said amplifier.

40. In an electric organ, a plurality of tuned tone generators, each including a magnetized reed and field coils, means joining said coils including variable resistances to control the currents induced in said coils when said reeds are vibrated, an amplifier connected to said field coils to alter the magnitudes of the currents passed by said resistances, a tone control for said amplifier including a condenser and a variable resistance, a plurality of loud speakers connected to said amplifier, microphones adjacent said reeds, an electronic mixer connected to said microphones, an amplifier connected to said electronic mixer, a tone control for said amplifier including a condenser and variable resistance, a loud speaker for said amplifier, an induction coil including a primary and secondary circuit, means connecting the primary circuit across the circuit of said last named speaker, and means connecting said secondary circuit to said field coils.

41. In an electric organ, a plurality of toned permanently magnetized reeds, field coils for said reeds, an amplifier connected to said field coils to alter the magnitudes of the currents induced in said coils when said reeds are vibrated, a tone control for said amplifier, a plurality of loud speakers responsive to different ranges of frequencies connected to said amplifier and resistance means for varying the loudness of tone of said speakers individually and as a unit.

42. In an electric organ, a plurality of toned magnetized reeds, field coils for said reeds, an amplifier connected to said field coils to alter the magnitudes of the currents induced in said coils when said reeds are vibrated, a tone control for said amplifier, a plurality of loud speakers responsive to different ranges of frequencies connected to said amplifier, resitsance means for varying the loudness of tone of said speakers individually and as a unit, microphones adjacent said reeds, an electronic mixer for said microphones, an amplifier for said microphones, a tone control for said amplifier, a loud speaker for said amplifier, and resistance means to control the loudness of tone of said speaker individually and as a unit with said first named group of speakers.

43. In an electric organ, a plurality of toned magnetized reeds, field coils for said reeds, an amplifier connected to said field coils to alter the magnitudes of the currents induced in said coils when said reeds are vibrated, a tone control for said amplifier, a plurality of loud speakers responsive to different ranges of frequencies connected to said amplifier, resistance means for varying the loudness of tone of said speakers individually and as a unit, microphones adjacent said reeds, an electronic mixer for said micro-

phones, an amplifier for said microphones, a tone control for said amplifier, a loud speaker for said amplifier, resistance means to control the loudness of tone of said speaker individually and as a unit with said first named group of speakers, and an induction apparatus including a primary winding connected across the circuit of said last named speaker and having its secondary winding connected to said field coils to combine the highest frequencies in the circuit of said last named speaker with the frequencies supplied by said reeds.

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