

Aug. 14, 1923.

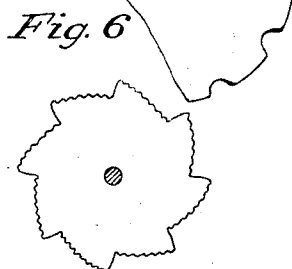
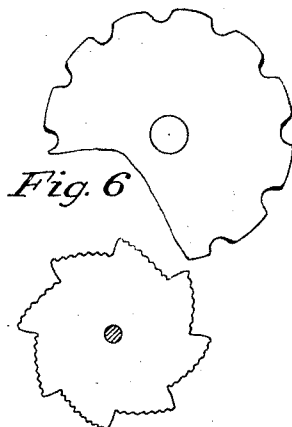
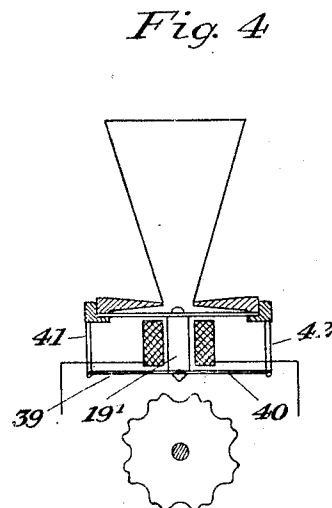
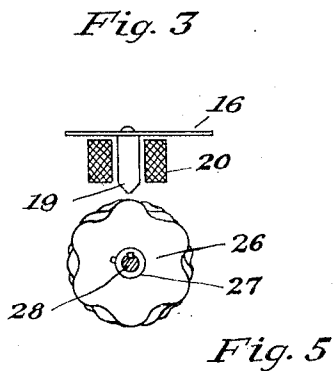
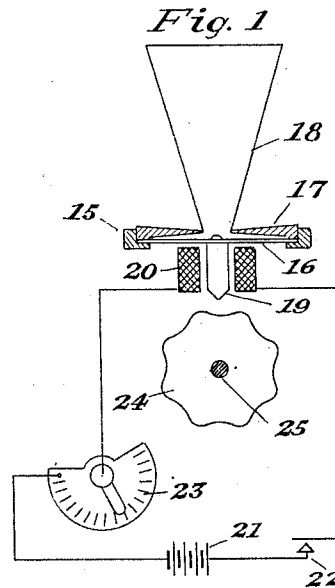
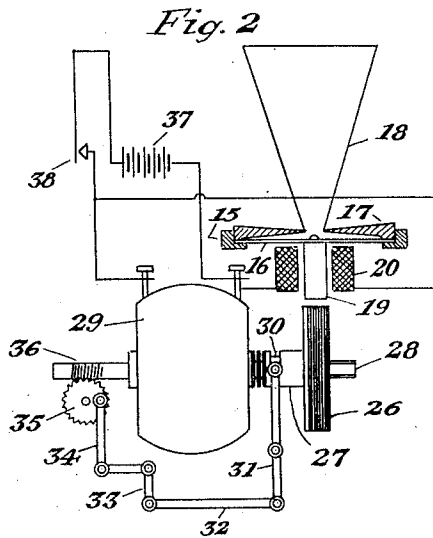
1,464,729

M. L. SEVERY

METHOD OF AND MEANS FOR PRODUCTION OF SONOROUS VIBRATIONS

Filed Oct. 6, 1917

2 Sheets-Sheet 1



Inventor
Melvin L. Severy
by Westall and Wallace
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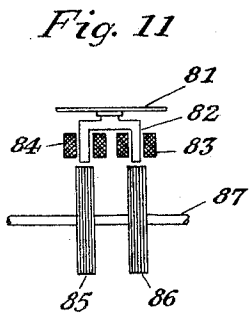
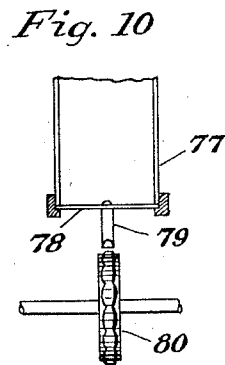
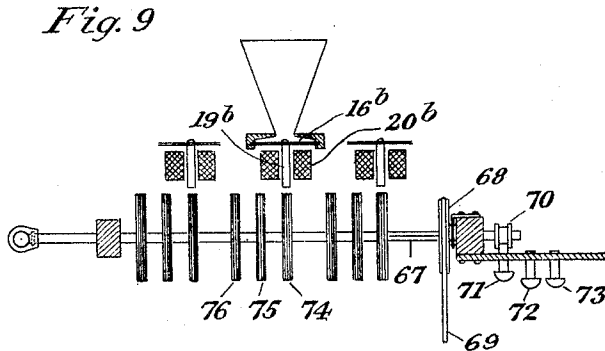
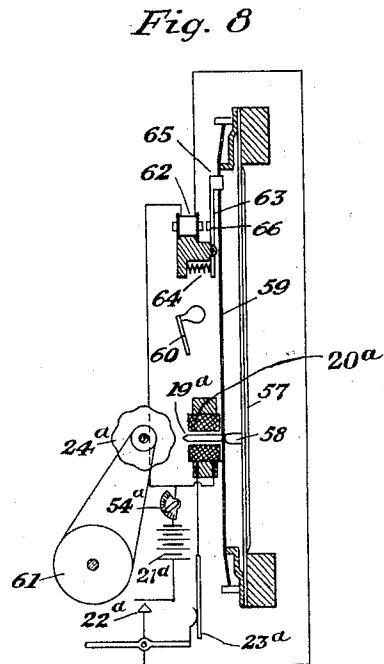
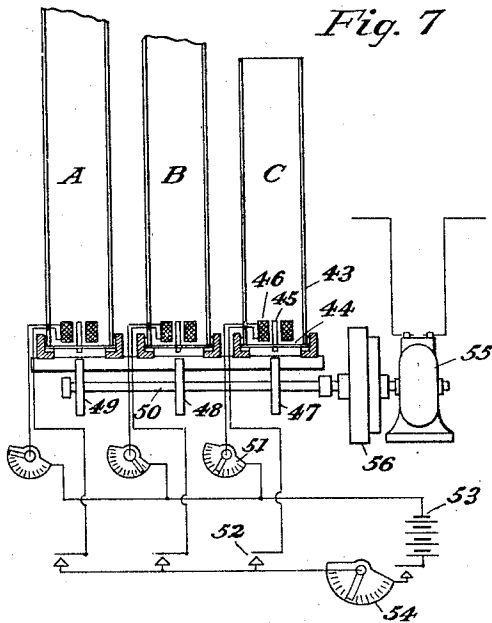
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M. L. SEVERY

METHOD OF AND MEANS FOR PRODUCTION OF SONOROUS VIBRATIONS

Filed Oct. 6, 1917

2 Sheets-Sheet 2



Inventor
Melvin L. Severy
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Patented Aug. 14, 1923.

1,464,729

UNITED STATES PATENT OFFICE.

MELVIN L. SEVERY, OF LOS ANGELES, CALIFORNIA.

METHOD OF AND MEANS FOR PRODUCTION OF SONOROUS VIBRATIONS.

Application filed October 6, 1917. Serial No. 195,077.

To all whom it may concern:

Be it known that I, MELVIN L. SEVERY, a citizen of the United States, residing at Los Angeles, in the county of Los Angeles and State of California, have invented new and useful Improvements in Methods of and Means for Production of Sonorous Vibrations, of which the following is a specification.

10 This invention pertains to a method of and means for producing sonorous vibrations, and is more particularly intended for the production of musical tones of any desired loudness, pitch, volume and quality.

15 Briefly stated, the method consists in controllably varying the air-gap between the pole or poles, core or cores, of a magnet (said pole or poles, core or cores being connected to or associated with and adapted to vibrate a body, as for example, a string, reed, sound-board, diaphragm, or the like, which is capable of sonorous vibration), and an armature of magnetic material extending into the magnetic field or field of force of such magnet. By so varying the air-gap with proper frequency, the force of attraction between the magnet and the co-acting armature, which latter is rotatably and adjustably fixed in space, is so varied as to cause the magnetized metal of the magnet and the vibrating body with which it is connected, alternately to approach and to recede from the associated armature, and thus to set up in the sonorous body vibrations of predetermined character, frequency and amplitude. The frequency, amplitude and character of the vibrations may be varied and controlled by varying the form, character, material, mass or speed of movement of the armature, or of that portion of the armature which extends into the effective portion of the magnetic field; by varying the nearness of said armature to the core or cores of said magnet; by varying the voltage of the energizing current or otherwise varying the strength of magnetization of said core or cores; by varying the character of the sonorous body; and in other ways.

50 The invention may best be embodied in a structure comprising any usual form of body capable of sonorous vibration and provided with a magnet, and with a rotor or armature composed of a disk or disks of magnetic material mounted upon a shaft and suitably rotated, the periphery of the disk or the pe-

ripheries of the several disks, being of such form as will, when rotated, oppose to the magnet pole or poles successively portions extending alternately further and less far into the effective portion of the magnetic field, and into closer and less close proximity to the magnet pole or poles.

60 To vary the quality or timbre of the tone produced, one or more disks or elements of a rotor may have a peripheral form or outline suitable to produce vibrations which will generate the fundamental, while another disk or disks may be so varied in form or outline as to influence the vibrations in a manner to produce or accentuate any desired overtones or partials of such tone, or even to produce inharmonic vibrations where desired. In this way wide variety of tone values is made possible.

75 In prior patents granted to me, or to myself jointly with George B. Sinclair, two methods of producing sonorous vibrations have been disclosed, the first consisting in fixing in proximity to a diaphragm, string, or other similar body, provided if need be with an armature of magnetic metal, an electromagnet, and alternately closing and opening the circuit of such electromagnet with a frequency corresponding to the frequency of vibration of said body in producing a tone of predetermined pitch; see for example, Patent No. 1,098,983, dated June 2, 1914.

80 Under the second method, an electric current was supplied to the electromagnet whose varying attractive force effected vibration of the sonorous body, and the current so supplied was rendered pulsatory by rotating in proximity to a metallic member included in the magnet circuit, a metallic rotor whose periphery presented alternate elevated and depressed portions, or alternate wide and narrow portions and consequently varying mass; see for example, Patent No. 1,190,332, dated July 11, 1916.

100 The present invention simplifies the construction and improves the operation of the mechanism by causing the magnetic rotor to act within the field of force of a magnet or magnet core directly carried by or connected with the sonorous body, which magnet may be either a permanent magnet or an electromagnet. Under the present plan, the magnetic rotor is so formed or fashioned as to vary the attraction between the mag-

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net and the rotor with a frequency corresponding to the frequency of vibration of the sonorous body in producing a note or tone of predetermined pitch, and further, when a somewhat complex tone is desired so to effect the vibrations as to add to the fundamental of the tone produced, one or more partials, and to give to each partial so added such strength as will, together with the fundamental, produce a composite tone of desired quality or timbre. Under the present plan the only mechanism requiring to be rotated or moved to produce the sonorous vibrations, is one or more shafts each provided with one or more rotors or armatures (simple or compound as desired), each vibrating an associated sonorous body, it being understood that while the invention may be applied to a single sonorous body and to produce a single note or tone, there will ordinarily be provided such number of magnets vibrating thin associated body or bodies, for instance, a sound-board, reeds, strings, diaphragms, pipes, or the like, as are necessary or appropriate to a complete musical instrument of the type or class desired. There may be one sonorous body or vibratory element common to all the magnets, as in the case of a sound-board; or several vibratory elements each common to a particular group of magnets, as several sound-boards or a subdivided sound-board; or an individual sonorous body or vibratory element for each magnet, as a string, diaphragm, reed, or the like.

In the accompanying drawings I have illustrated more or less diagrammatically the manner of embodying or applying my present invention. In these drawings:

Figure 1 shows a horn suitable for use as a warning signal on automobiles and other vehicles;

Figure 2 is a somewhat similar view, showing also means for automatically changing the character of the tone produced;

Figure 3 is a face elevation of a rotor or armature composed of a plurality of disks or laminae, the respective peripheries of which bear outlines of differing wave-form, number, or both;

Figure 4 illustrates an apparatus of the character shown in Fig. 1, but with a somewhat different form of rotor and with means to prevent lateral movement or displacement of the magnet or magnet core;

Figure 5 is a face view of a rotor disk (partially broken away), the peripheral outline of which is substantially that suitable to the production of vibrations giving a simple tone;

Figure 6 is a face view of a rotor, the periphery of which has large primary elevations and depressions with smaller elevations and depressions between their high

and low points, such form when used in connection with the sonorous body, educing a tone somewhat similar to that produced by a violin string;

Figure 7 is a diagrammatic illustration of a section of a musical instrument employing resonators and vibrating diaphragms equipped with means for varying the loudness or intensity and tone quality of the notes educed;

Figure 8 illustrates the invention applied to a sound-board of the piano type, here shown as equipped also with strings which may, however, be omitted;

Figure 9 illustrates the invention as applied to horns equipped with vibrating diaphragms, means being shown for changing the timbre or tone quality of the notes educed;

Figure 10 illustrates a resonator with vibrating diaphragm and an armature or rotor, the peripheral portion of which is concentric with the axis of rotation but is of wave form on its side faces, thereby giving variable mass in such peripheral portions;

Figure 11 shows a diaphragm equipped with a magnet of the horse-shoe type, each pole of which is opposed to a separate rotor or armature.

Referring first to Fig. 1, 16 indicates a diaphragm clamped or held in a casing comprising a centrally perforated disk member 17 and a clamping ring 15, between which parts the diaphragm is clamped at its outer edge. Extending from the central opening of the body or disk 17 is a horn 18, for gathering and directing the sound-waves produced by vibration of the diaphragm 16. Centrally located upon and secured to said diaphragm 16 is a magnet core 19, freely movable axially within a fixed winding or coil 20 of insulated wire, which latter is included in the circuit of a battery or source of electric energy, 21. Said circuit also includes a circuit-closing switch or key 22, and a rheostat 23 for regulating the delivery of current to the coil 20 of the electro-magnet.

24 represents a disk the periphery or inductively active portion of which is of wave form, the disk being flat and the sinuosity being produced by varying the distance between the axis of rotation and the periphery throughout the circumference thereof. This disk constitutes a rotor or armature, and is carried by a rotatable shaft 25. Shaft 25 will be turned at such speed as will carry the alternate elevations and depressions of the disk through the magnetic field of and past magnet core 19 with a frequency corresponding to the rate of vibration necessary to the production of the predetermined note. As current flows constantly through the coil 20 so long as the circuit is closed at the key 22, diaphragm 16 will be caused to

vibrate with a frequency corresponding to the number of rotations of the rotor or armature 24 multiplied by the number of elevations on the periphery of said rotor. Such vibration of course is due to the fact that when the air-gap is shortened, the force of attraction between the magnet core 19 and the disk or rotor 24 increases, and as the gap lengthens such force decreases. As attraction between a magnet and its armature is reciprocal, the magnet core 19 will move toward and from the rotor or armature as the latter rotates, thereby throwing the diaphragm into vibration.

By varying the resistance in the circuit of battery 21 and magnet 19—20, or as will be self-evident, altering the electro-motive force of said battery 21, the strength of the magnet and magnetic field may be varied as desired. This in turn will vary the amplitude of the vibrations of diaphragm 16 and the consequent loudness or intensity of sound.

When the device is used merely as an alarm or signal, the circuit-closer 22 may be of any usual form, as a small swinging lever, push button, or the like, while in the case of a musical instrument it may be a contact carried by a key of the keyboard.

Figure 2 shows the same mechanism illustrated in Fig. 1, except that the rheostat 23 is omitted, and there is shown means for automatically varying the timbre or tone quality of the note educed during the time that the magnet circuit is closed. The electromagnet, diaphragm, diaphragm casing or holder, and horn, are as in Fig. 1. An electric motor 29 is indicated, the shaft 28 of which takes the place of shaft 25 of Fig. 1, and carries a rotor 26 which in the present instance is represented as a composite rotor or armature built up of a series of disks or timbre-forms, as similar disks have been designated in certain of my prior patents. The motor 29 receives current from a battery or source 37 when the circuit is completed by the closing of a switch 38. The magnet winding or coil 20 is in a branch or shunt from the circuit of source 37.

Rotor 26 is carried by a sleeve 37 axially movable upon shaft 28, but splined or otherwise so connected with said shaft as to compel joint rotation. Sleeve 27 is provided with a circumferential groove 30, which receives a pin or stud carried by a lever 31 which is connected by means of a link 32, elbow-lever 33 and link 34 with a crank-pin of a worm-wheel or disk 35, the periphery of which is furnished with worm teeth to engage a worm 36 formed upon or carried by shaft 28. This connection between the worm or disk 35 and the slidable sleeve 27, for which any equivalent intermediate connection may be substituted, causes a reciprocating movement of the sleeve 27 and the

rotor 26 so long as shaft 28 continues to turn and to rotate the worm-wheel 35. Such movement of the shaft and rotor causes the disks constituting the rotor 26 to move cross-wise of the magnet core 19, so that the disks are successively moved more or less into and out of the magnetic field, or into and out of close proximity to said magnet.

The separate disks making up the rotor 26 are of different form according to the tone quality desired; in other words, one or more of the disks have the form suitable to the production of the fundamental of the tone desired, while others are fashioned to produce selected partials, or where desired inharmonic vibrations. As the rotor moves across the magnet core or pole, the vibrations of the diaphragm 16 will be varied as the different disks enter or recede from the position of strongest mutual attraction between the disk and the magnet core, and a tone of constantly changing quality will result. By varying the forms of the respective disks, by setting them with their projections and depressions in varying angular relation to the shaft, or by combining the two variations, a wide range of tone quality may be secured, and this whether it be desired to produce truly harmonic effects or to introduce, for any reason, more or less weak inharmonic partials or dissonances.

If it be desired to emphasize the fundamental or any selected partial or partials, the disk having the form necessary to educe such fundamental or such selected partial or partials may be duplicated or repeated. Ordinarily, in the form illustrated in Fig. 2, the disk or disks producing the fundamental will be located at the midlength of the series so as to keep such disk or disks constantly in the stronger part of the field, those for the harmonics being distributed, according to the result desired, on either side thereof.

As illustrated in Fig. 3 the proper positioning of the several disks is simply and effectively insured by providing the sleeve 27 with a spline and forming a spline seat in each disk, set in such angular relation to the elevations and depressions of the periphery as shall bring the elevations and depressions of the respective disks into proper relation and maintain them there. This figure also illustrates a rotor composed of three disks the peripheries of which differ in number and dimensions of the wave-forms which they respectively bear, and it also illustrates the above-described manner of effecting and maintaining the relative angular adjustment of the several disks, but it is obvious that any common and equivalent means of holding the disks in fixed relation to one another may be employed, such as rivets or bolts passing through the series.

Figure 4 shows another form of rotor or armature disk, and also indicates posts or

stems 41, 42 carried by the clamping ring of the diaphragm shell or casing, and projecting therefrom in the same general direction as does the magnet core 19'. 39 and 40 indicate wires, tapes, cords, or the like, connecting the magnet core 19' with the posts or stems 41, 42, and serving to hold the magnet core against lateral displacement.

Figures 5 and 6 show forms of disk or rotor suitable respectively for the production of vibrations resulting in a simple tone and in a tone approaching or having some of the characteristics of that produced by a violin string.

It may be stated here that the specific shapes or forms of the respective rotors do not, per se, constitute a feature of the present application. I have heretofore devised and patented mechanical means for developing and producing these forms.

Figure 7 shows a series of resonator pipes, each with its separate loudness-control rheostat and key, and also a loudness-control common to all the pipes, so that any pipe may be sounded with any loudness at any time and in any combination. This may be used for a signal system or for one of the synthetic tone-groups of a musical instrument.

In said Figure 7, A, B and C indicate respectively resonators, each comprising a pipe 43 having at its lower end a diaphragm 44 provided with a magnet core 45 encircled by and freely movable within a coil or bobbin 46 of insulated wire, each coil in the embodiment here illustrated connected in parallel with the circuit of a battery 53, or other source of electric energy. The circuit or branch of each magnet coil is provided with a loudness-control rheostat 51, and a switch, circuit-closer or key 52. The main battery circuit is provided with a general loudness-control individual to the more or less composite tone elicited, in the form of a rheostat 54, and may have an additional switch or circuit-closer for permanently cutting out or bringing in the battery corresponding to what in a complete musical instrument would be a key of the key-board. 47, 48 and 49 indicate rotors, which may be simple or compound, respectively extending into the fields of force of the magnets of the several resonator diaphragms, said rotors being here shown as simple, the most common form where tones are to be synthetically built up. These rotors are carried by a shaft 50 rotated by a motor 55.

A synchronizer 56 is employed to maintain a constant speed of rotation for the shaft 50, or what is more important, a constant relative speed of the several rotor shafts where more than one such shaft is used. The synchronizer may be of any known type capable of maintaining the requisite uniformity of speed, such, for in-

stance, as shown in my Patent No. 1,163,473, or No. 1,186,851.

The rheostats 51, of which as stated there is one for each resonator and diaphragm, serve to control the supply of current to the respective magnets 45, and thus to control and determine the relative loudness or intensity of sound of the individual diaphragms and resonators, while the rheostat 54 serves to control the loudness or intensity of sound educed by the several diaphragms and resonators as a group. Obviously, the effect produced by the use of rheostat 54 may be secured by bodily adjustment of the shaft 50 of Fig. 7 and its rotors toward or from the magnet cores, or by like adjustment of the magnet cores toward or from said shaft and rotors, or by varying the voltage of the energizing source 53, after the manner clearly set forth in U. S. Patent No. 1,171,668 granted to me jointly with George B. Sinclair, and dated February 15, 1916.

I have shown the magnets arranged within the lower end of the resonator pipes A, B and C, in which position I prefer to place them, but this is not obligatory. The magnets may be placed below the diaphragms or outside the pipes, but by arranging them on the side of the diaphragm opposite that which faces the rotor, the use of stays to prevent lateral displacement of the magnets through drag of the rotor is rendered unnecessary, while the action in producing vibration remains the same. Distortion or unsymmetrical flexure of the diaphragm is thus prevented, and a pure tone insured.

In Figure 8, 57 indicates the sounding board of a piano or like instrument, and 60 indicates the head of a hammer of the piano action, the remainder of such action being omitted as unnecessary to the present description. The instrument, as shown in said figure, is provided with strings 59, only one of which is seen in said figure, each string having a magnetic damper control in general principle such as set forth in certain of my prior patents. This comprises for each string, an electromagnet 62 placed in proximity to a soft iron armature 66 of a damper lever 63 provided with the usual felt damper 65, which is normally pressed against the strings by a distended spring 64. The electromagnet 62 is included in the circuit of a battery or other source 21^a, which when a circuit-closer 22^a completes the battery circuit, as it does on the depression of the corresponding key, energizes said magnet 62 and withdraws the damper 65 from the string. Also included in said circuit or a derivative thereof, is the fixed coil or winding 20^a of an electromagnet, the movable core 19^a of which is secured to the bridge 58 of the sounding board 57. In front of and extending into the magnetic fields of the magnet cores 19^a

are rotors 24^a, here shown as rotated by a belt, passing about a drive-wheel 61 and a pulley on the shaft which carries said rotors, or in any usual way. It is to be understood that the strings are not essential and may be wholly omitted, the sound-board being sufficient in itself to generate the necessary sound-waves when thrown into vibration. I have shown in Fig. 8 only such parts as are necessary to make clear the nature of my invention, the details thereof being reserved as proper subject-matter for future applications. As stated, the string 59, damper, etc., may be omitted.

In Figure 9 I have illustrated a group of three vibratory diaphragms or bodies 16^b, each provided with a magnet core 19^b movable freely in an axial direction through a fixed coil or winding 20^b, and associated with each magnet, a group of three rotor units, each unit designed to produce characteristically different vibrations of the diaphragm or body with which it is at any time associated. As illustrated in Fig. 9, each rotor group comprises three units 74, 75 and 76, suitably spaced apart and made fast to a shaft 67. Each rotor 74, 75 and 76 may be, and in Fig. 9 is represented as, composed of a plurality of disks designed respectively to produce, when rotated in proximity to its associated magnet core, the fundamental tone desired with any selected partial or partials. Each of said rotors 74, 75 and 76 carries disks designed to call forth, when rotated in proximity to its associated magnet core, either the fundamental with selected partials differing from those of the companion rotors of the unit, or the same partials, but in varying loudness determined by the mass given to the respective disks of the individual rotors. The shaft 67 is splined through a portion of its length so that it may slide axially through a drive wheel 68, but may not rotate independently of the wheel. The wheel 68 is held against axial movement but is free to rotate, turning with it the splined shaft 67, said wheel receiving motion through a belt 69 or equivalent means. At one extremity the shaft 67 is provided with a grooved collar 70, which through longitudinal movement of said shaft may be brought into alinement with any one of several stops or locking-pins 71, 72 or 73, which are so positioned and spaced as to hold in plane with the respective magnets 16^b the right-hand, medial, or left-hand rotor unit of their respective groups. The opposite extremity of shaft 67 is provided with a swivel head or other means of connection with a lever or device for effecting the axial movement of said shaft, to bring into active relation to a given magnet the particular rotor unit desired.

By this means instruments having one or

another given type of vibrating body may be caused to produce sounds or tones simulating more or less closely different or varied instruments, or sounds characteristic of a single instrument but varying in tone quality. In other words, an instrument can be built under the present invention capable of simulating other known instruments, or of simulating the combined effects of several other and different instruments, or of simulating even human voices.

Obviously, the illustrated means of adjusting and holding the shaft 67 are simply suggestive, and may be replaced by any of various constructions common in the art for effecting like adjustments.

In Figure 10 there is shown a resonator pipe 77 having a vibratory diaphragm 78 with a permanent magnet 79 centrally attached thereto, said magnet extending toward a rotor 80, the periphery of which is cylindrical but of varying width. In other words, the peripheral portion of the rotor has fluted or scalloped side faces. As a consequence of this construction, such peripheral portion extending into the field of magnet 79 and being there rotated, will present rapidly varying magnetic mass opposite the pole of said magnet, thus alternately strengthening and weakening the magnetic field, and causing corresponding increasing and diminishing attraction between the magnet and armature. As the armature is rotatably and adjustably fixed in space while the magnet, owing to the flexibility of its supporting diaphragm, is axially movable, said magnet will approach and recede from the rotor as the portions of said rotor of greater and of lesser mass pass through the magnetic field and in proximity to the magnet pole.

In Figure 11 I have shown a horse-shoe electromagnet core 82 carried by the diaphragm or vibrating body 81, and having separate coils 83 and 84 fixed in space and through which the poles of the magnet freely move in an axial direction. Opposed to the respective poles are rotors 85 and 86, which usually, though not invariably, will be of identical character, said rotors being carried by a shaft 87 rotatable in fixed bearings, as shown in various of the other figures. This form gives opportunity for more powerful attraction of the magnet and diaphragm than does the single core magnet.

It is of course understood in every instance that the rotors or the peripheral portions thereof which traverse the magnetic field, will be of iron or other magnetic or magnetically inductive material.

In Figs. 7 and 9 the numerals are applied to only one of the diaphragms, coils, etc., the construction of all being identical and hence rendering numeral designation of each unnecessary.

It is particularly to be noted that under the present invention a peculiarly simple structure is produced, in which there is an entire absence of friction, rubbing or wear in the electrical portions of the apparatus; that any quality of tone may be produced by an instrument through simply employing rotors of one or another configuration, which configurations may readily be standardized and cheaply reproduced; and that the only parts of the mechanism requiring to be power driven are the rotor shafts with their rotors, and these require very small expenditure of power.

The musical effects in the matter of loudness or softness, varying tone quality, gradation, and the like, are almost limitless. The entire apparatus is simple, relatively inexpensive, easy of installation, change and repair, and not liable to derangement by ordinary meteorological conditions.

On the strictly musical side the advantages are very marked. Thus the sonorous wave can be made exactly what is desired, and great purity of tone is secured. The method and the instrument are especially adapted to synthetic tone production and make possible the production or generation of any fundamental tone with any desired partials or overtones; in other words, the tone quality of each note can be controlled and varied as desired, and musical instruments can be furnished having those peculiar qualities which the differing tastes of highly trained musicians demand. This may be done regardless of certain defects inherent in various reproducing systems. By way of illustration it may be noted that diaphragms, which possess the quality of reproducing a wide range of musical tones, commonly or frequently respond unduly to or reproduce with undue emphasis, certain tones to which they are peculiarly sensitive. Such over-accentuated tones mar the general result, or in some instances even produce a tone other than that intended. By the present system such defect may readily be compensated for or neutralized through the employment of rotors having their peripheries specially designed to that end, by the use of a plurality of rotors of given configuration, by the inclusion or elimination of selected partials, by combining two or more of these modes of varying the tone quality, and in other ways. As before indicated, the designing and development of the requisite curves is a matter which can be certainly and accurately accomplished by simple means heretofore devised and patented.

Obviously, this mode of production or generation of sound-waves is applicable in practically all cases where a single note or any range of notes is required, as for instance, in connection with automobile horns,

fire alarms, sirens, fog horns, musical instruments of simple tones compounded synthetically, musical instruments of composite tones made directly, scientific instruments to illustrate tone changes, musical toys, and organs. The sound produced may if preferred be made unmusical and raucous, as where it is desired suddenly and certainly to arrest attention. Phonograms or rotors capable of causing words or articulate speech to be shouted, are readily possible through the use of the system and apparatus here set forth.

This invention is not confined to the use of rotating or revolving bodies to create vibration of the sonorous body. Any means of moving the requisite sinusoidal form past the magnet or vice versa, may be employed, as for instance, an endless belt, a disk or wheel having the wave surface formed upon or applied to its side face, and the like.

It is obvious that like effects may be produced by varying the air-gap between the magnet and the rotor, or varying the mass of magnetic material passing through the magnetic field in proximity to the magnet pole or poles. Both plans are illustrated in the drawings, the latter in Fig. 10. The two plans may be combined in one rotor if desired.

In Figs. 2 and 9 I show a means for altering the intensity of the tones produced by armatures revolving adjacent energized magnet-cores, such movement in the case of Fig. 9 being in some instances sufficient practically to quench the action of one armature, and subsequently, if continued far enough, to initiate the action of another armature. This variation is accomplished by increasing or decreasing the air-gap between the magnet-cores and their associated armatures. In the case of Fig. 9 the gap may,—and stop mechanism is provided so that it shall,—at times be so increased as progressively to silence, or entirely cut out of the effective magnetic circuit, certain of the armatures. In Fig. 2, however, the intensities of the tones produced by the armature elements are automatically altered by the automatic increase or decrease of the distance from their associated magnet-core or cores. Obviously, this variation of air-gap produces the same result as the rheostat 54 (when such rheostat is of infinite gradation, being an improvement thereon when it is in the more usual stepped form), and will often be the cheapest and most convenient way of securing the result. It is of course self-evident that any means of varying the extent of this air-gap will produce the result secured by the rheostat 54, and is clearly within the scope of my invention. For example, I may secure the expressional effect of rheostat 54 by altering the distance between the magnet-core or cores and the as-

sociated armature or armatures by movements sensibly parallel to the direction of said cores, as shown in my Patent No. 1,218,324, dated March 6, 1917, or in my Patent No. 1,190,332, dated July 11, 1916, or in the patent granted to George B. Sinclair and myself, numbered 1,137,544 and dated April 27, 1915.

I desire it understood that any loudness variation produced by any variation of the air-gap is clearly within the scope of and covered by my invention.

Some of the rotors here shown are similar in construction to the laminated rotors set forth in Patent No. 1,137,544, granted to myself and George B. Sinclair, and dated April 27, 1915, in that they may be made up of separate laminae. In Figs. 2, 3, 9 and 11 of the drawings accompanying this application, as in the patent just referred to, the rotors are made up of such laminae, each bearing upon its periphery wave-forms, and the wave-forms of the several laminae being placed in the same or in different angular relation to the axis of rotation. The rotors now under consideration, however, differ from those of said Patent No. 1,137,544 in that the wave-forms of different laminae are unlike, certain thereof being appropriate to the production of magnetic pulsations to educe the fundamental of the desired tone, and others to educe selected partials thereof. In other words, through the employment of such composite or laminated rotor unit or element, the magnetic flux and the mutual attraction of the magnet core and armature are so varied as to produce the predetermined tone or note with such quality or character as may be desired. This composite or laminated construction is, however, not always necessary or desirable (see, for instance, Fig. 7).

While I have shown the magnet or magnet core as directly secured to and carried by the vibrating body and prefer such arrangement, it is obvious that it may be separately mounted and guided, and connected with the vibrating body through intermediate means.

It is particularly to be noted that under the present invention the electromagnets are either energized by a direct current of normally constant voltage, which, however, may be varied by the introduction or withdrawal of resistance into and from the magnet circuit or circuits, or by a current the voltage of which may be changed at will, in order to decrease or increase the loudness or intensity of sound; and further, that vibration of the sonorous body is effected by directly varying, with the requisite frequency, the magnetic gap between each magnet core connected with a sonorous body, and the rotor associated with such magnet core, or by varying the mass of magnetically

inductive material of the armature moving through the field of each magnet, or finally, by combining the two effects. This mode of producing or generating sonorous vibrations and determining the loudness or intensity of sound and quality of tone educed, avoids entirely the use of pulsatory currents, and I believe to be broadly new.

It is to be noted that the rotor disks or laminae are, in their more usual form, provided with angularly spaced peripheral portions which may be and ordinarily will be, of like form and mass though not always so, and that these peripheral sections may be further divided into successive elevations and depressions, or successive portions of greater and less mass, as illustrated in Figs. 4 and 6. In other words, the wave-forms, as these separate peripheral sections are commonly termed, are repeated or recurrent and will be so referred to in certain of the claims.

It is to be understood that that portion of the armature which is formed with recurrent sections of varying outline or mass, or both, extends in such proximity to the magnet cores as to be in the stronger portion of the magnetic field, or in other words, in the effective field of the magnet, and the term "effective field" is used in some of the claims with this significance. This recurrent or repetitious variation is applicable both to rotors or armatures having disks of the simple form illustrated in Figs. 1, 3, 8 and 10, and to rotors such as illustrated in Figs. 4 and 6 having recurrent or repetitious groups of variations, or in other words, in which minor variations are formed in the peripheral sections of the disks constituting the major variations.

It is likewise to be understood that in the preferred form of my invention, the sonorous body vibrated by means of electromagnets is of the sound-board type and is acted upon by a plurality of magnets, the sound-board or sound-boards being either one integral body or in separate parts or sections as preferred. In any event, in this preferred form, the sections or areas of the sound-board or vibratory body will be acted upon, each by a plurality of magnets. The specific construction of the sound-board is not herein set forth or claimed, as that may vary and will be set forth in one or more separate applications, though any usual type may be employed.

In this invention moving armatures are made to cause motion in magnets or the cores thereof, associated with or attached to sonorous bodies, and while, for convenience, I usually prefer to attach or associate only the cores of the magnets with the sonorous bodies, it is obvious that I may also, upon occasion, associate with, or attach the entire magnets to, said sonorous bodies. When,

therefore, in the claims reference is made to the cores of magnets as attached to, connected, or associated with sonorous bodies, I desire it to be understood that, except where permanent magnets are used, the other parts of the magnets may or may not be so circumstanced.

From the foregoing description it will be understood that the peripheral portion of each rotor or armature, or that portion which traverses the effective magnetic field of any magnet-core of the instrument, is specially formed according to the effect sought to be produced in the vibration of the sonorous body with which the magnet-core is associated. To this end it is desirable that each distinct section of the armature, while the same as other sections of the same armature, vary in mass and in form from its leading to its trailing extremity, this variation being effected by increasing or decreasing the transverse or cross-sectional area of the section radially, axially, or on any other line that will cause different armature masses to be presented to the magnet-core as any given section of the armature passes through the effective field of the magnet-core. This is the meaning of the expression "formed projections" occurring in one or more of the claims.

Having thus described my invention, what I claim is:—

1. The method of producing musical tones which consists in connecting with a body capable of sonorous vibration, a magnet-core provided with means for energizing the same; and moving through the effective field of said core an armature of magnetically inductive material provided with regularly recurring sections, each section being of unequal mass at different points in the direction of movement of the armature, successive sections being caused to pass through the magnet field with a frequency corresponding to the frequency of vibration necessary to produce the predetermined tone.

2. The method of producing tones in musical relation, which consists in moving armatures of magnetically inductive material and of relatively different outline, through the effective fields of magnet-cores each connected with and serving to impart vibrations of a different frequency to a sonorous body, each armature having its peripheral portion divided into recurrent or repetitious sections, each section of a given armature being of unequal mass at different points in the direction of its movement, and successive sections of each armature being caused to traverse the effective field of its associated magnet-core with a frequency corresponding to the frequency of vibration necessary to produce the predetermined tone.

3. The method of producing musical tones of desired quality, which consists in moving

through the effective field of a magnet-core provided with means for its energization, and connected with a body capable of sonorous vibration, an armature of magnetically inductive material, different parallel zones of said armature having their peripheries provided with recurrent sections, each section of a given zone similarly differing in mass at different points in the direction of movement of the armature, and the several zones of the armature being fashioned respectively to educe, when moved in unison and at proper speed, vibrations of the sonorous body of frequencies to produce a complex tone with selected partials.

4. The method of producing musical tones of desired quality, which consists in moving through the effective field of a magnet-core provided with means for its energization and connected with a body capable of sonorous vibration, a laminated armature of magnetically inductive material, each lamina having successive portions of like form and dimensions but varying in mass in the direction of movement of the armature, the successive portions of each lamina differing from those of some of the other laminae in form and mass, said armature being moved at a speed suitable to produce sonorous vibrations of frequencies to educe the desired fundamental of the predetermined tone and to educe or emphasize selected partials of said tone.

5. The method of producing musical tones which consists in moving through the field of a magnet-core having means for its energization and connected with a body capable of sonorous vibration, an armature of magnetically inductive material having successive portions of like form and mass, each such portion of unequal mass at different points in the direction of travel of the armature, said armature being moved at a sensibly constant predetermined speed, whereby its portions of progressively increasing and decreasing mass in passing through the effective magnetic field vary the inductive action and the attractive force of the magnet-core and effect vibration of the sonorous body, the successive portions of the armature being moved through the effective magnetic field with a frequency to educe the fundamental of the tone desired.

6. The method of producing musical tones of any desired pitch and quality, which consists in providing means capable of sonorous vibration with electromagnets for vibrating the same in accord with fluctuations of the several magnetic circuits; and moving through the effective field of any selected magnet or magnets a magnetically inductive armature, each armature having a plurality of sections differing in mass at different points in the direction of its travel and differing in number in the several armatures,

one of said armatures being fashioned to produce in its magnetic circuit when moved at a proper speed, pulsations of the periodicity of the fundamental of the desired tone, and another or others thereof being fashioned to produce, each in its magnetic circuit, pulsations of a periodicity corresponding to some other partial of the predetermined tone.

7. An apparatus for the production of sonorous vibrations, comprising a body capable of sonorous vibration; a magnet for vibrating the same; a continuous armature of magnetically inductive material movable through the effective portion of the magnet field, and having that portion which enters said field varying with recurrent sections similarly varying in mass and outline in the direction of movement; and means for imparting to said armature a sensibly constant speed of movement through said part of the magnetic field.

8. An apparatus for the production of musical tones, comprising a body capable of sonorous vibration; a magnet for vibrating the same; an armature of magnetically inductive material, a part of said armature movable about an axis and through a portion of the field of said magnet, the portion of said armature moving through said field being made up of equally spaced recurrent sections each varying in mass and outline in the direction of rotation of the armature; and means for imparting to said armature a predetermined and sensibly constant speed of movement such as will carry said recurrent sections past the magnet with a frequency equal to the frequency of vibration necessary to educe a tone of the predetermined pitch.

9. An apparatus for the production of musical tones of predetermined pitch and quality, comprising a body capable of sonorous vibration; a magnet for vibrating the same; a laminated armature of magnetically inductive material rotatable about its axis and having its peripheral portion movable through the effective field of said magnet, the peripheral portion of each lamina being made up of equally spaced sections, each of varying mass and outline in the direction of travel at least one of the laminae being fashioned to produce vibrations giving the fundamental of the desired tone, and another or others thereof being fashioned to supplement or modify the vibrations in a manner to add or to accentuate a selected partial or partials of such tone; and means for imparting to said armature a predetermined speed of movement such as will carry said peripheral sections past the magnet core with a frequency equal to the frequency of vibration necessary to educe a tone of predetermined pitch.

10. In an apparatus for producing sonorous vibrations, the combination of a body

capable of sonorous vibration; a magnet core associated therewith; an energizing coil encircling said core; a source of electric energy in circuit with said coil; an armature of magnetically inductive material extending into the field of said magnet, and having the portions adapted to pass by said core composed of recurrent sections, each section varying in mass and outline in the direction of its travel; means for adjusting the said armature to different positions in the field of said magnet; and means for rotating said armature at a sensibly constant, predetermined speed.

11. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibration; a magnet core connected therewith; a fixed energizing coil encircling said core; a source of electric energy in circuit with said coil; an armature of magnetically inductive material extending into the field of said magnet and having the portion within said field composed of a series of like sections, each section varying in mass and outline in the direction of its travel; and means for moving said armature in a fixed path through the field of said magnet at predetermined and constant speed, the magnet core being free to move within and independent of its energizing coil.

12. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibration; a magnet core connected with said body and projecting mainly from the front face thereof; a fixed coil encircling said core but detached therefrom; a rotating armature of magnetically inductive material placed on the same side of the vibrating body as the main body of the magnet core, said armature extending into the field of said magnet and having the portion adapted to move through the field of said magnet composed of a series of sections, each section varying in mass and outline in the direction of its travel; and means for moving the armature through said field at a sensibly constant speed such as will present successive sections thereof opposite the magnet core with a frequency corresponding to the normal frequency of vibration of the sonorous body in educing the fundamental of a tone of predetermined pitch.

13. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibration; a magnet core for vibrating the same; an energizing coil encircling said core; a source of electric energy in circuit with said coil; an armature of magnetically inductive material extending into the field of said magnet and having a portion within said field, of varying mass and outline in the direction of its travel; means for moving said armature through the field of said magnet at a predetermined

speed; and means for varying the attractive force between the magnet core and its associated armature.

14. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibration; a magnet core for vibrating the same; an energizing coil encircling said core; a source of electric energy in circuit with said coil; an armature of magnetically inductive material extending into the field of said magnet, and having a portion within said field of varying mass and outline in the direction of its travel; means for moving said armature through the field of said magnet at a predetermined speed; and means for adjusting the distance between the magnet core and the axis of the armature.

15. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibration; a magnet core for vibrating the same; an energizing coil encircling said core; a source of electric energy in circuit with said coil; means in circuit with said source of energy for varying the voltage of current delivered to said coil; an armature of magnetically inductive material extending into the field of said magnet and having a portion adapted to move through said field, said portion composed of a series of sections each section varying in mass and outline in the direction of its travel; and means for moving said armature through the field of said magnet at a predetermined speed.

16. An apparatus for producing sonorous vibrations, comprising a body capable of sonorous vibration; a magnet for vibrating said body; an armature of magnetically inductive material projecting into and movable through the field of said magnet, said armature having its inductively active portion formed with a series of sections, each section varying in mass and outline in the direction of movement of the armature, whereby such movement will cause variation of the air-gap between the magnet and armature; and means for moving said armature at a speed to carry the armature sections through the magnetic field with a frequency corresponding to the frequency of vibration of the sonorous body when educing a predetermined tone.

17. An apparatus for producing sonorous vibrations, comprising a body capable of sonorous vibration; a magnet core connected therewith; a motor; a magnetically inductive rotor splined and axially movable upon the shaft of said motor; a worm carried by the motor-shaft; a worm-wheel meshing with said worm; and connections between said wheel and the splined sleeve, whereby the rotor is automatically moved axially along the shaft, said rotor being composed of a plurality of disks each having a sinuous

periphery projecting into the field of the magnet, the outlines of the several disks differing from one another.

18. An apparatus for producing sonorous vibrations, comprising a body capable of sonorous vibration; a magnet-core connected with said sonorous body; a magnetically inductive armature or rotor having a periphery of sinusoidal form extending into the effective field of said magnet-core; an energizing coil for said core; a source of electric energy in circuit with said coil; means for rotating the armature; and means for moving the armature axially to carry it more or less into and out of the effective magnetic field.

19. A musical instrument comprising a series of magnet-cores each provided with an energizing coil and each associated with a sonorous body to which it communicates vibrations; a source of electric energy for said coils; a switch or key for opening or closing each coil circuit independently; a series of magnetically inductive rotors, one such rotor associated with each of said magnet-cores and projecting into the effective field thereof; means operable at will for increasing or diminishing the force of attraction between the magnet-cores and their associated rotors; means for rotating said rotors, each rotor having its periphery formed with like recurrent sections equally spaced angularly about the axis of the rotor and each varying in mass at different points in the direction of travel; and speed-controlling means serving to maintain a uniform rotation of the rotors at a rate of speed which will cause successive peripheral sections of each rotor to traverse the magnetic field with a frequency corresponding to the characteristic frequency of vibration of its associated sonorous body in producing some predetermined partial of the desired tone.

20. A musical instrument comprising a series of bodies each capable of sonorous vibration and each provided with a magnet core; separate energizing coils for the respective magnet cores; a source of electric energy to which the energizing coils are joined; a switch or key for opening and closing each respective coil circuit independently; rheostats individually variable, included in the coil circuits; means operable at will for varying the degree of the attractive force between all of said magnets and their coating armatures simultaneously; a series of magnetically inductive rotors, one for each magnet and acting as armature thereto, each projecting into the effective field of its associated magnet; means for rotating said armatures; and speed-controlling means for determining the speed of rotation of said armatures, the several armatures being fashioned and proportioned al-

ternately to increase and diminish the attractive force between each magnet and its associated rotor with a frequency to educe some predetermined partial of the tone desired.

21. In a musical instrument the combination of a series of magnet cores each surrounded by an energizing coil, and each core associated with and adapted by its movement to vibrate a sonorous body; a source of electric energy; means operable at will and individual to each magnet for causing said source of energy to energize any of said coils; groups of rotor units; means for rotating said groups at a predetermined speed, certain units of each group arranged to rotate at a given time opposite the core of the associated magnet; means, operable at will, for similarly rotating other units of said groups, the rotors of the several units being formed of magnetizable material and when rotated at suitable speed introducing into the magnetic circuits of their respective magnets, fluctuations corresponding in frequency to the frequency of some selected partial of the sonorous body when educing a tone of the predetermined pitch.

22. In a musical instrument of the character described, a series of magnets each associated with and capable of vibrating a sonorous body; a rotor for each magnet, projecting into the field thereof, each rotor composed of a series of laminae, each lamina having a periphery formed with recurrent sections varying in mass and outline in the direction of rotation, one or more of the laminae of each rotor being fashioned to create pulsations suitable to educe the fundamental of the predetermined tone, and others of the laminae being fashioned to add to or modify such vibrations as to educe or accentuate a selected partial or partials of such tone.

23. In a musical instrument, the combination of a body capable of sonorous vibration; a magnet-core connected with and serving to communicate vibratory movement thereto; an energizing coil for said core, including a source of electric energy; an armature having a peripheral portion provided with a series of like sections uniformly spaced, each section of different mass at different points in the direction of its movement, said peripheral portion extending into and movable through the effective field of the core; and means for moving said armature sections at a sensibly constant speed, whereby the spaced sections are caused to pass successively through the effective field with a frequency corresponding to the frequency of vibration of the sonorous body when giving off the predetermined tone for which the armature is designed, the alternate increase and decrease of armature mass within the effective field

serving correspondingly to increase and decrease the attractive force of the magnet-core, and consequently to effect vibration of the sonorous body.

24. In a musical instrument of the character described, a body capable of sonorous vibration; a horse-shoe magnet core associated with said body and serving to communicate vibratory movement thereto; energizing coils, one for each magnet leg or pole; and an armature rotatable about its axis and having its peripheral portion formed of magnetically inductive material, extending into the effective field of said magnet and facing the poles thereof, said peripheral portion being provided with a series of equally spaced like sections, each section of different mass at different points in the direction of its travel.

25. A musical instrument comprising resonant means; a plurality of magnet-cores associated therewith and serving to communicate vibration thereto; means for independently energizing and de-energizing any or all of said cores at will; armatures of magnetically inductive material, respectively associated with the respective magnet-cores, and provided with peripheral sections of like form each varying in mass and form at different points in the direction of its travel, said sections being movable through the effective fields of the magnet-cores with which they are respectively associated; and means for moving successive sections of each armature through its magnetic field with a frequency to produce in the resonant means, vibrations of a periodicity conforming to the characteristic periodicity of the associated resonant means in producing a predetermined tone of the musical scale.

26. A musical instrument comprising resonant means of the sounding-board type; a plurality of magnets associated therewith and communicating vibration thereto; means for energizing and de-energizing said magnets at will; a plurality of armatures associated with said magnets, portions of said armatures being movable through the fields of said magnets, said portions being formed with recurrent variations in mass and outline; and means for imparting to said armatures a suitable rotative speed.

27. In an apparatus for producing sonorous vibrations, the combination of a body capable of sonorous vibrations; a magnet-core connected therewith; an energizing coil encircling said core; a source of electric energy in circuit with said coil; a laminated armature of magnetically inductive material extending into the field of said magnet, the periphery of each lamina having like and equally spaced formed projections varying in mass and outline at different points in the direction of its travel, the projections

of one lamina differing from those of another; and means for moving the formed projections of said armature through the effective field of its magnet at a predetermined speed suitable to educe from the sonorous body selected partials of the predetermined tone.

28. A musical instrument comprising resonant means; a plurality of magnets associated therewith and capable of communicating thereto vibrations of the relative ratios subsisting in the musical scale selected; means, operable at will, for energizing and de-energizing any of said magnets; rotatable armatures of magnetically inductive material associated with said magnets, each operating when rotated, to cause its juxtaposed magnet and associated resonant means to vibrate whenever said magnet is energized; means for imparting to said armatures a suitable and sensibly constant rotative speed; and means for varying at will the degree of attraction subsisting between the magnets and their associated armatures.

29. A musical instrument comprising a series of magnets, preferably one for each note of the musical scale selected; resonant means to which said magnets communicate vibrations; means, operable at will, and including a source of electrical energy, for energizing and de-energizing any of the said magnets independently of any of the others; armatures of magnetically inductive material, a part of each armature mounted to move through the field of its associated magnet, and having adjacent inductively active portions of different mass and conformation; means, including a source of electric energy, for rotating said armatures; and means, operable at will, for determining the degree of attractive force exerted at any one time between the magnets then energized and their associated armatures.

30. A musical instrument comprising a series of magnets, preferably one for each note of the musical scale selected; resonant means to which said magnets communicate vibrations; means, operable at will, and including a source of electric energy for energizing and de-energizing any of said magnets independently of any of the others; armatures of magnetically inductive material, a portion of each armature adapted at any one time to rotate opposite the core of its associated magnet; means operable at will, for effecting relative adjustment of the armature and associated core in the direction of the axis of said armature, each armature having its inductively active portion formed in successive sections of mass and outline varying at different points in the direction of rotation; means, including a source of electric energy, for rotating said armatures; and means, for increasing or diminishing at will and for any desired period

of time the degree of attractive force exerted between the magnets then energized and the portions of their associated armatures then coacting with them.

31. Means for producing musical tones of desired timbre, comprising a series of magnetic circuits, one for each note of the musical scale selected; means, operable at will for energizing and de-energizing any of said circuits independently of any of the others; resonant means to which the vibrations caused by the fluctuations of said circuits are communicated; armatures of magnetically inductive material included in and constituting parts of the magnetic circuits, having their inductively active portions of different mass and outline in the direction of travel; means for rotating said armatures at suitable speed and thereby causing said fluctuations; and means, operable at will, for regulating the strength of said fluctuations and the amplitude of the vibrations of said resonant means.

32. Means for producing musical tones of desired timbre, comprising a series of magnetic circuits, one for each note of the musical scale selected; means, operable at will for energizing and de-energizing any of said circuits independently of any of the others; resonant means to which the vibrations caused by the fluctuations of said circuits are communicated; armatures of magnetically inductive material formed to cause, when rotated, circuit fluctuations of predetermined strength and frequency relative to each other and to the simultaneous fluctuations of the other circuits; and means for rotating said armatures at suitable speed past the poles of their associated magnets, to create the said fluctuations in the said circuits and in their associated resonant means.

33. Means for producing musical tones, comprising a series of magnetic circuits, one for each note of the musical scale selected; means, operable at will, for energizing and de-energizing any of said circuits independently of any of the others; sonorous means to which the vibrations caused by the fluctuations of said circuits are communicated; armatures of magnetically inductive material formed to cause, when rotated, circuit fluctuations of predetermined strength and frequency relative to each other and to the simultaneous fluctuations of the other circuits; means for rotating said armatures at suitable speed past the poles of their associated magnets, to create the said fluctuations in the said circuits and in their associated sonorous means; and means, operable at will, for increasing and decreasing the strength of said fluctuations as a whole while preserving their relative values.

34. Means for producing musical tones of desired pitch and timbre, comprising a series of magnetic circuits, one for each note of

the musical scale selected; means, operable at will, for energizing and de-energizing any of said circuits independently of any of the others; sonorous means to which the vibrations caused by the fluctuations of said magnetic circuits are communicated; armatures of magnetically inductive material formed to cause, when rotated, magnetic circuit fluctuations of predetermined strength and frequency relative to each other and to the simultaneous fluctuations of the other circuits; means for rotating said armatures at suitable speed past the poles of their associated magnets, to create the said fluctuations in said magnetic circuits and in their associated sonorous means; means, operable at will, for increasing and decreasing the strength of said fluctuations as a whole while preserving their relative values; and means, operable at will, for changing the characteristics of the fluctuations by rendering inductively active portions of said armatures which previously were inductively inactive,

and thereby altering the quality of the tone educed.

35. In a musical instrument, the combination of a sonorous body; a magnet-core connected with said body and serving to communicate vibratory movement thereto; means for energizing said core; and a normally unmagnetized rotor included in circuit with the energizing coil of the magnet-core, for producing when rotated, pulsations in said circuit and consequent variations in the attraction between the magnet-core and the rotor, said rotor comprising a plurality of laminae of magnetically inductive material, each lamina being a disk the radii of which are of different lengths at different angular points, certain of said laminae being of conformation different from that of the others.

In witness I claim the foregoing, I have hereunto subscribed my name, this 28th day of Sept., 1917.

MELVIN L. SEVERY.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,464,729, granted August 14, 1923, upon the application of Melvin L. Severy, of Los Angeles, California, for an improvement in "Methods of and Means for Production of Sonorous Vibrations," errors appear in the printed specification requiring correction as follows: Page 2, line 22, for the word "thin" read *their*; page 9, line 17, claim 7, for the word "varying" read *provided*; page 10, line 117, claim 20, strike out the word "respective" and insert the same to follow the article "the" in line 119; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of November, A. D., 1923.

[SEAL.]

KARL FENNING,
Acting Commissioner of Patents.