Feb. 28, 1933. M. L. SEVERY 1,899,884

ELECTRICAL MUSICAL INSTRUMENT

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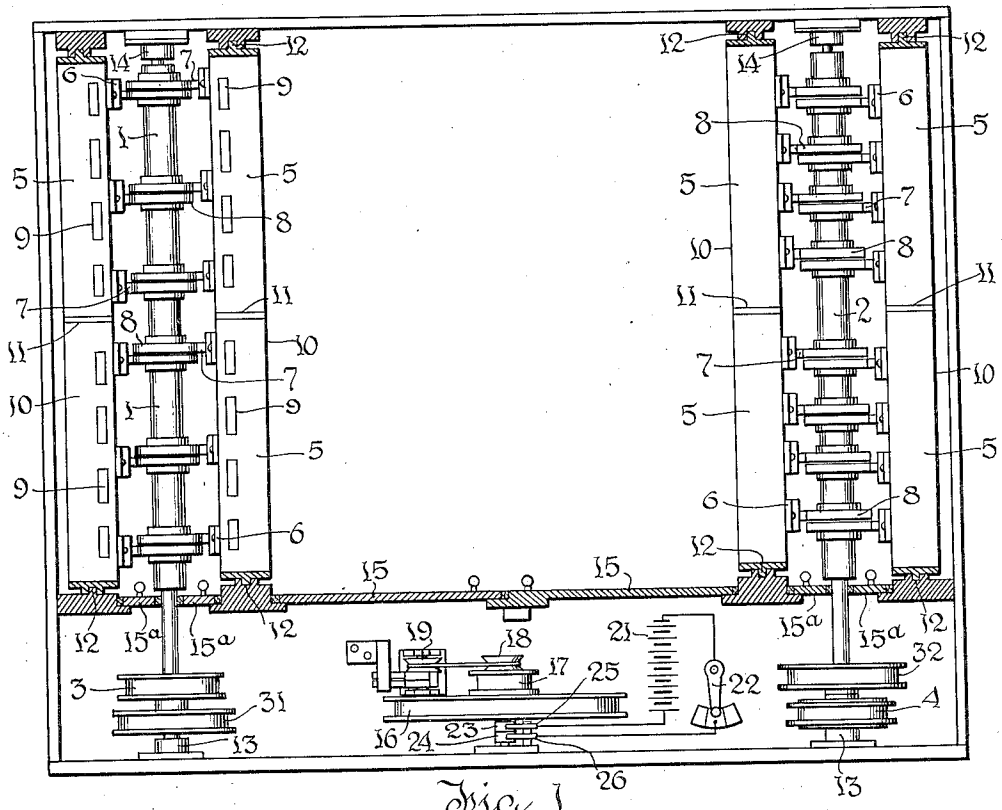


Fig. 1

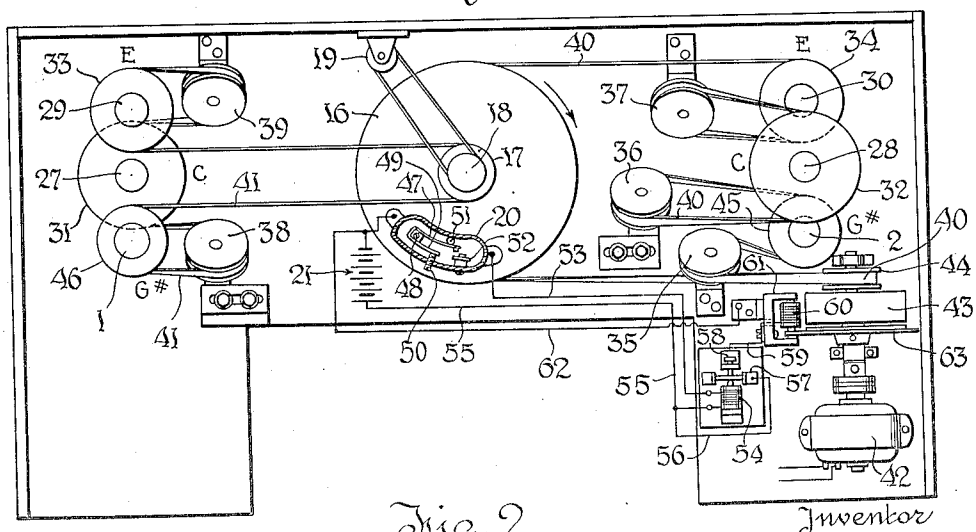


Fig. 2

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Fig. 4

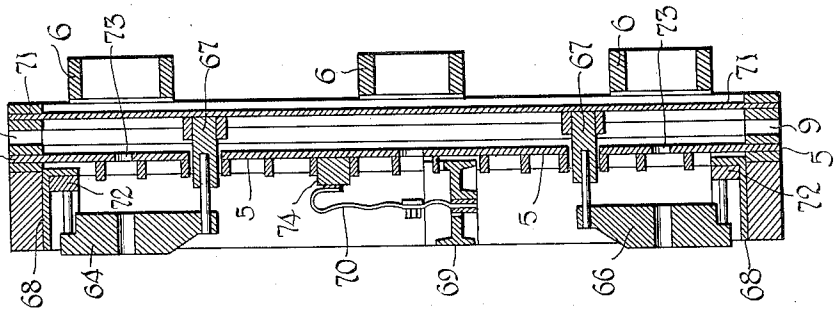
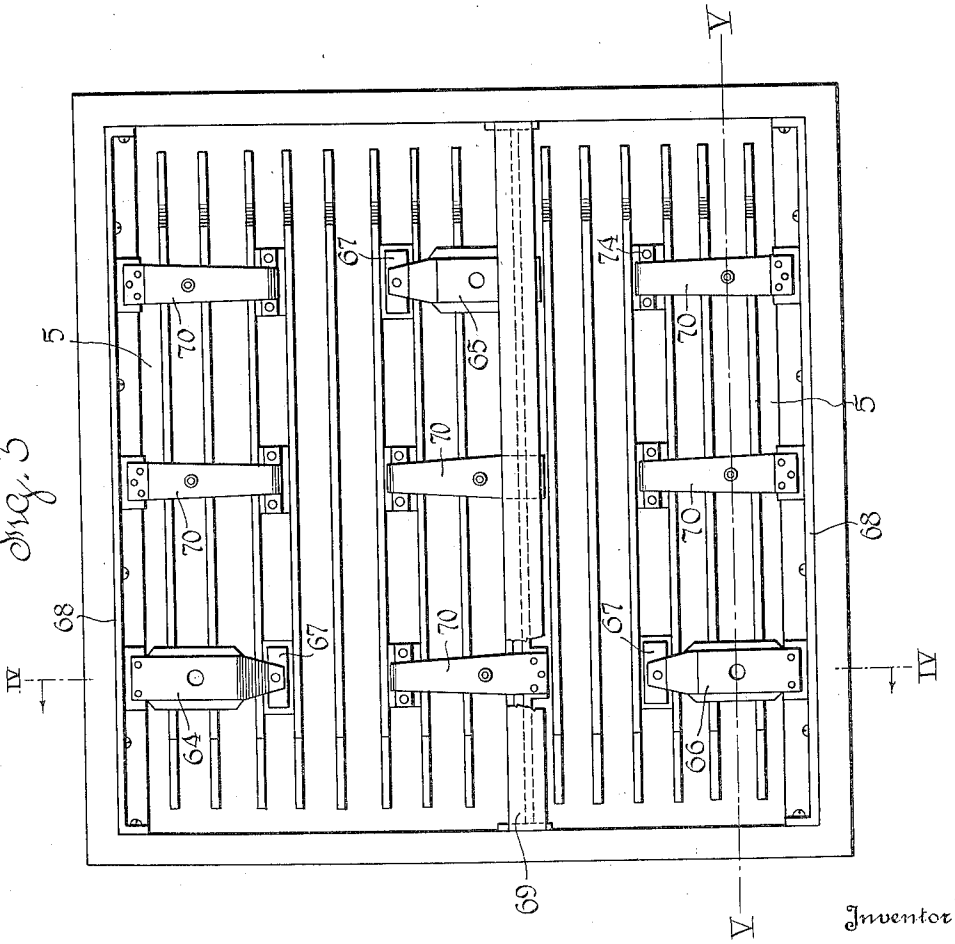


Fig. 3



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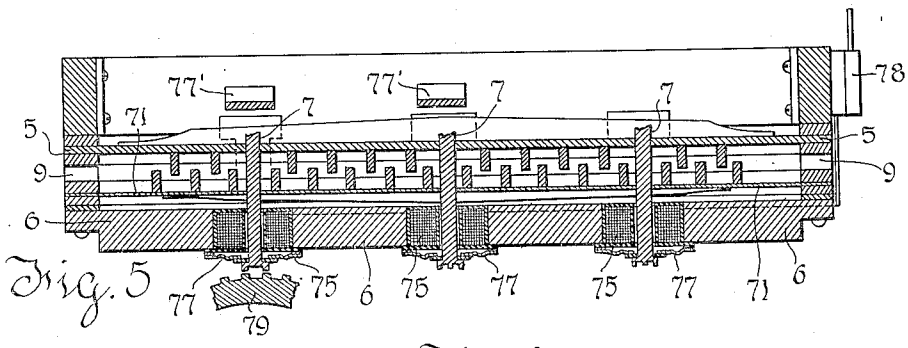


Fig. 5

Fig. 6

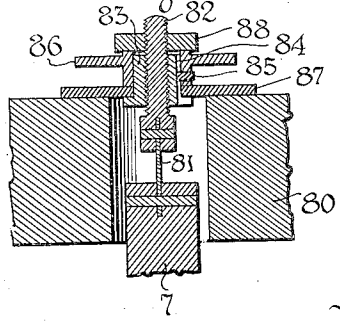


Fig. 7

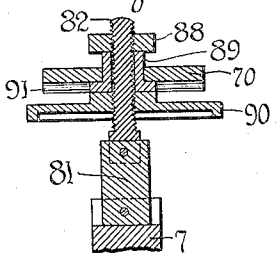


Fig. 8

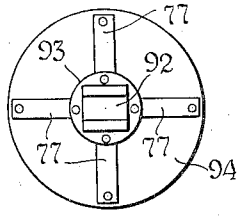


Fig. 9

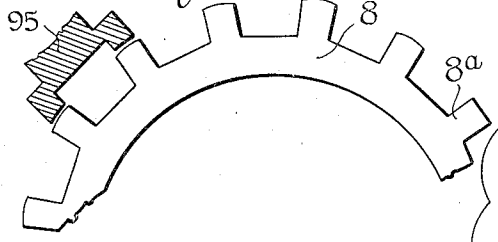
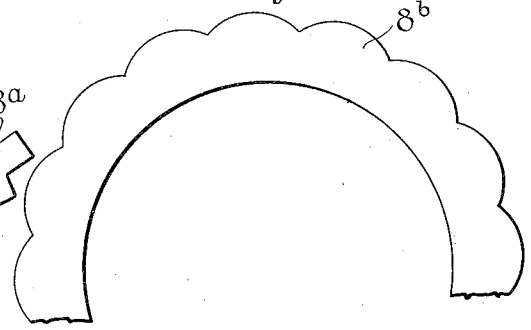


Fig. 10



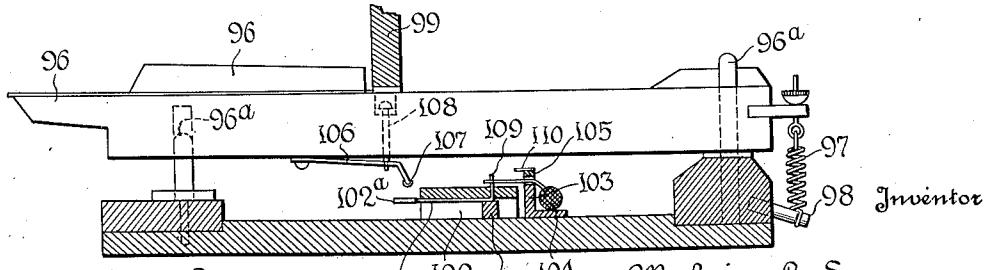


Fig. 11

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Fig. 12

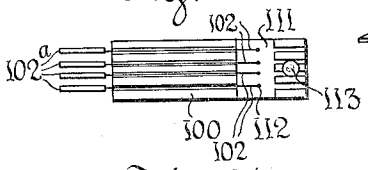


Fig. 13

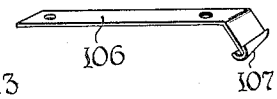


Fig. 17



Fig. 16

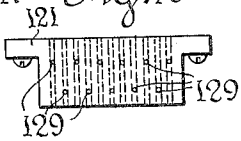


Fig. 14

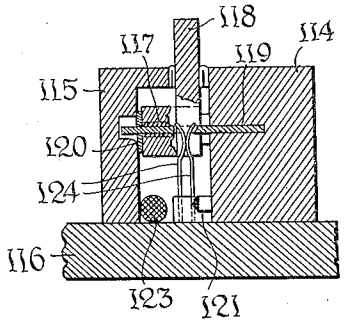


Fig. 15

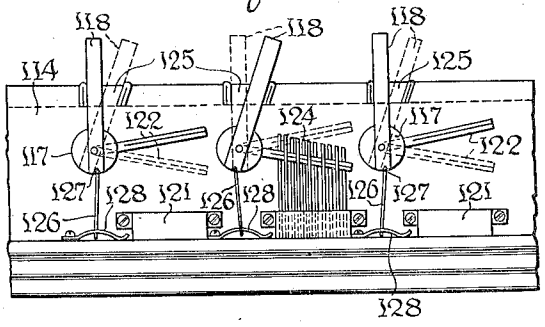
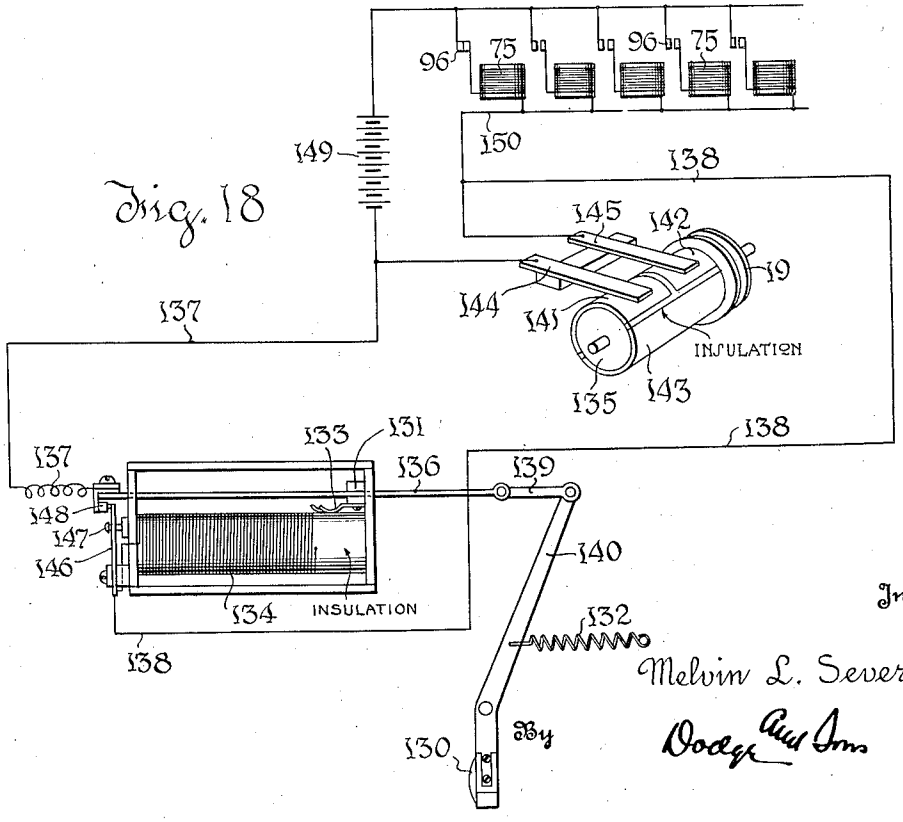


Fig. 18



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Fig. 19

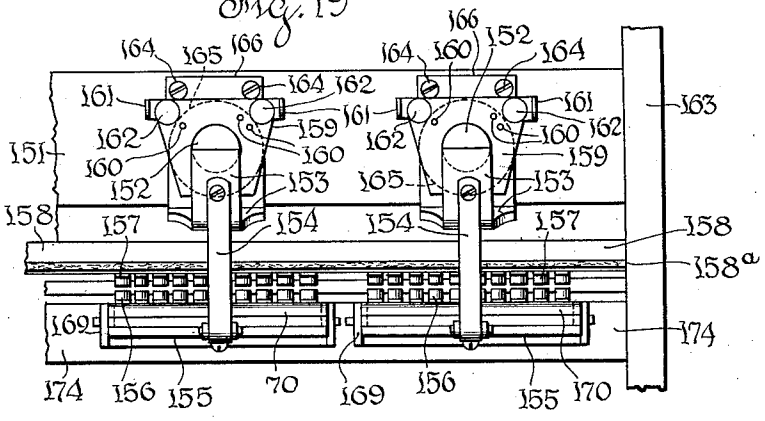


Fig. 21

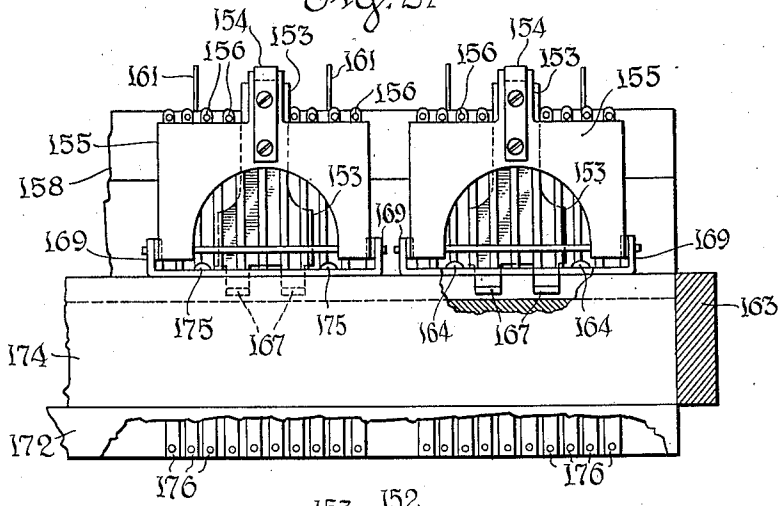
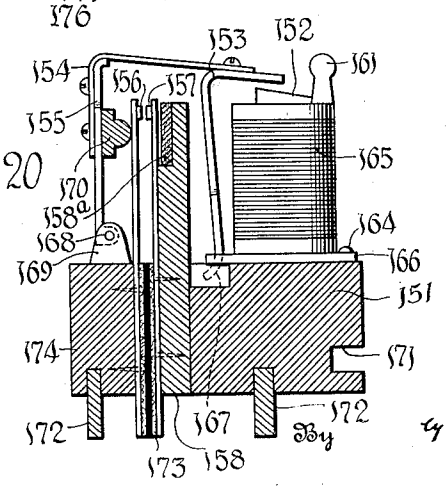


Fig. 20



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Fig. 22

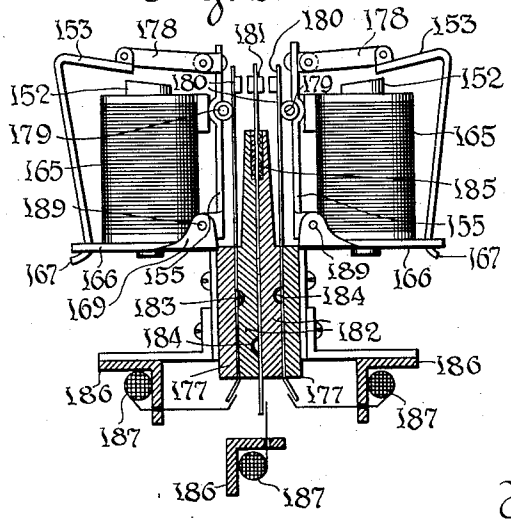


Fig. 23

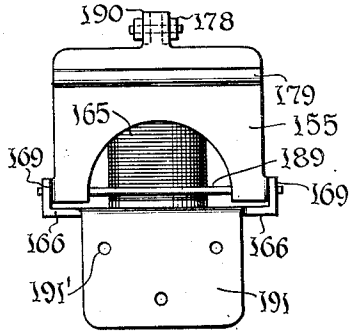
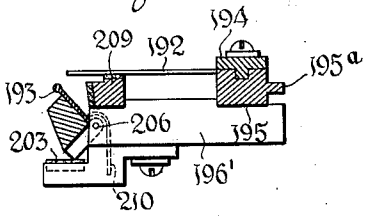


Fig. 25



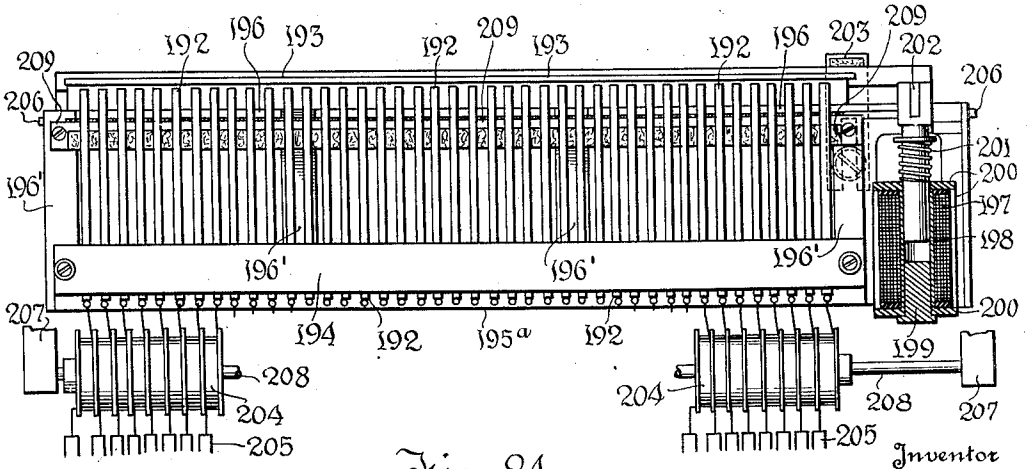


Fig. 24

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By Dodge and Inn.

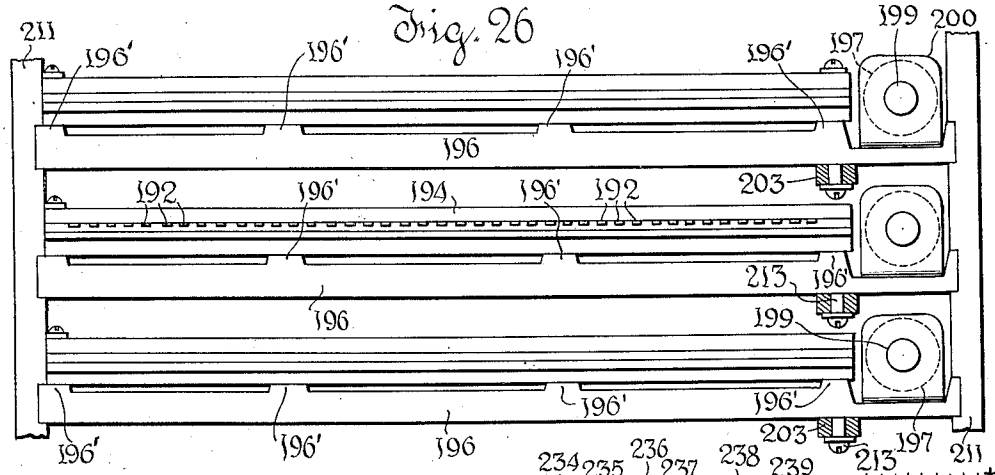
Attorneys

Feb. 28, 1933. M. L. SEVERY 1,899,884

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Fig. 26



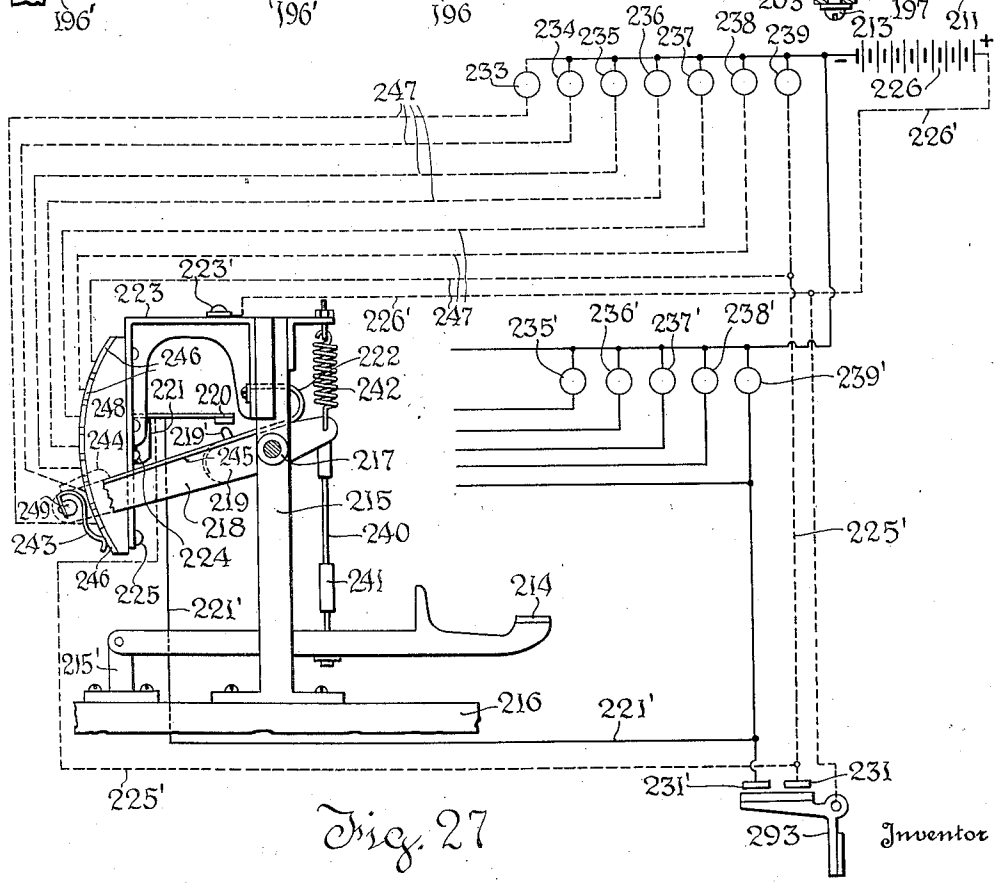


Fig. 27

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Fig. 28

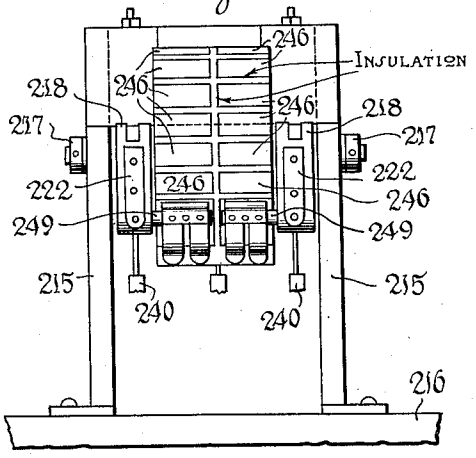


Fig. 29

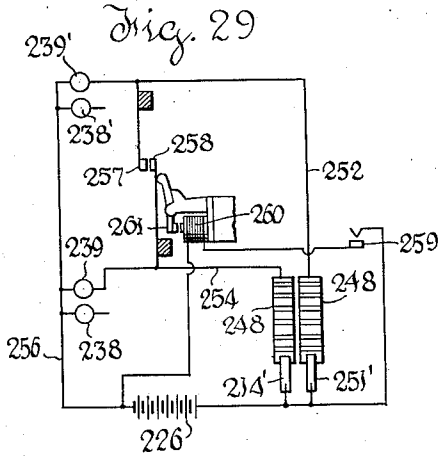


Fig. 30

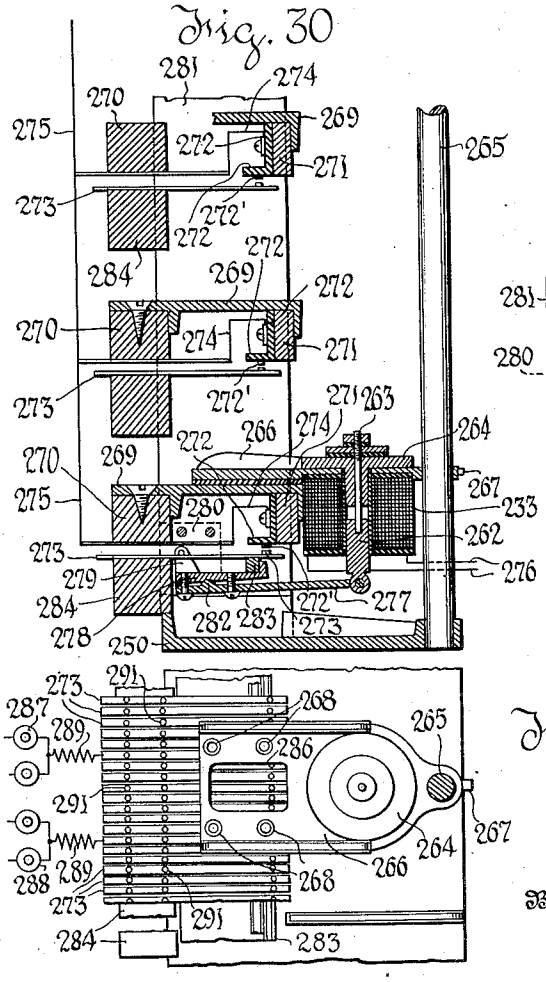


Fig. 31

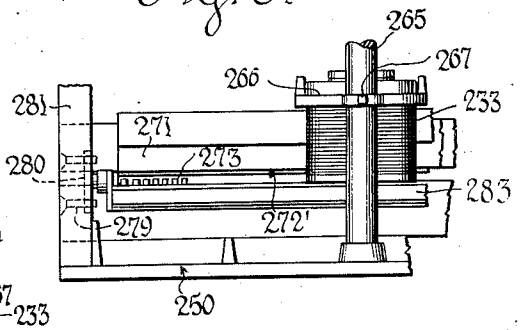


Fig. 32

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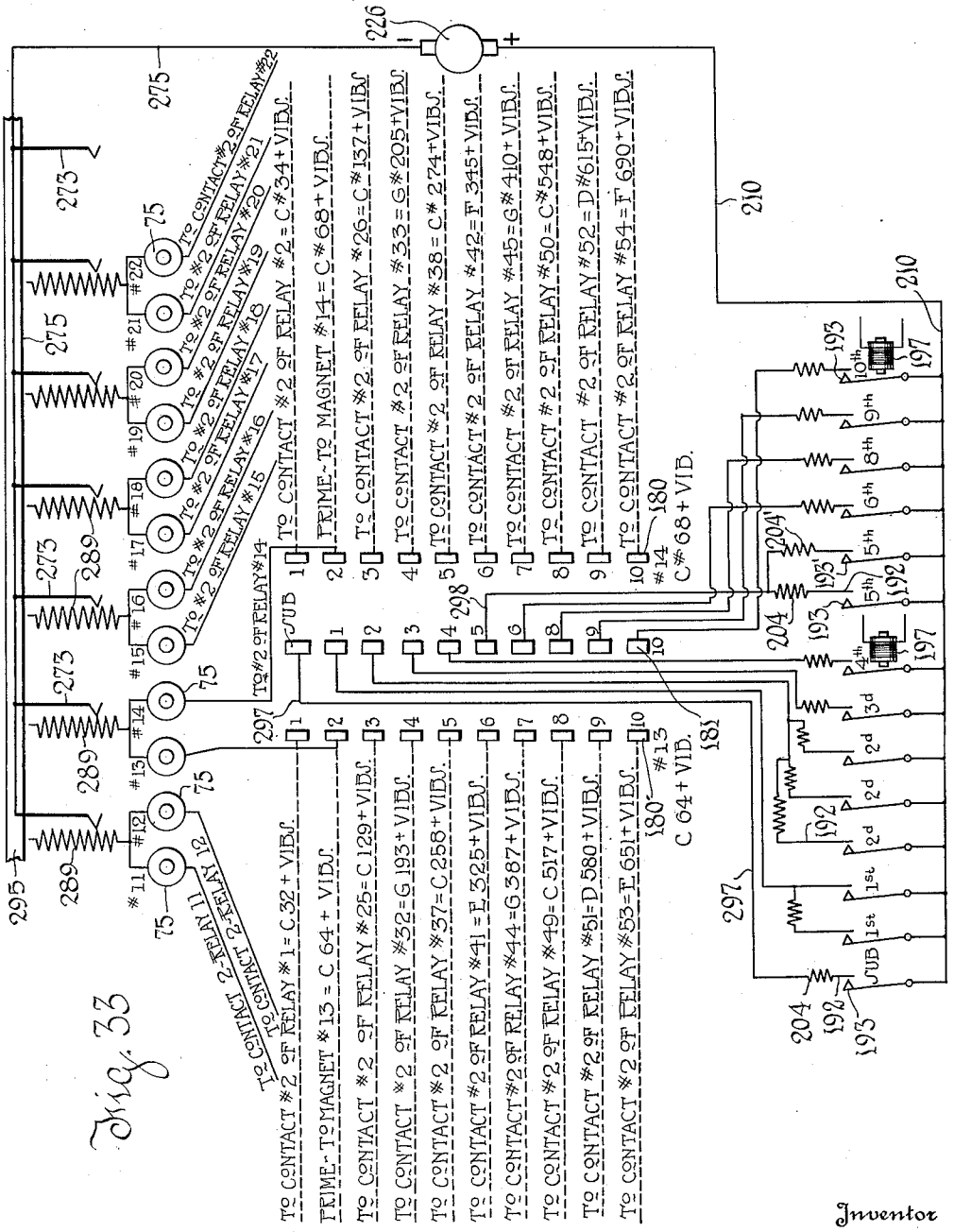


Fig. 33

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Feb. 28, 1933. M. L. SEVERY 1,899,884

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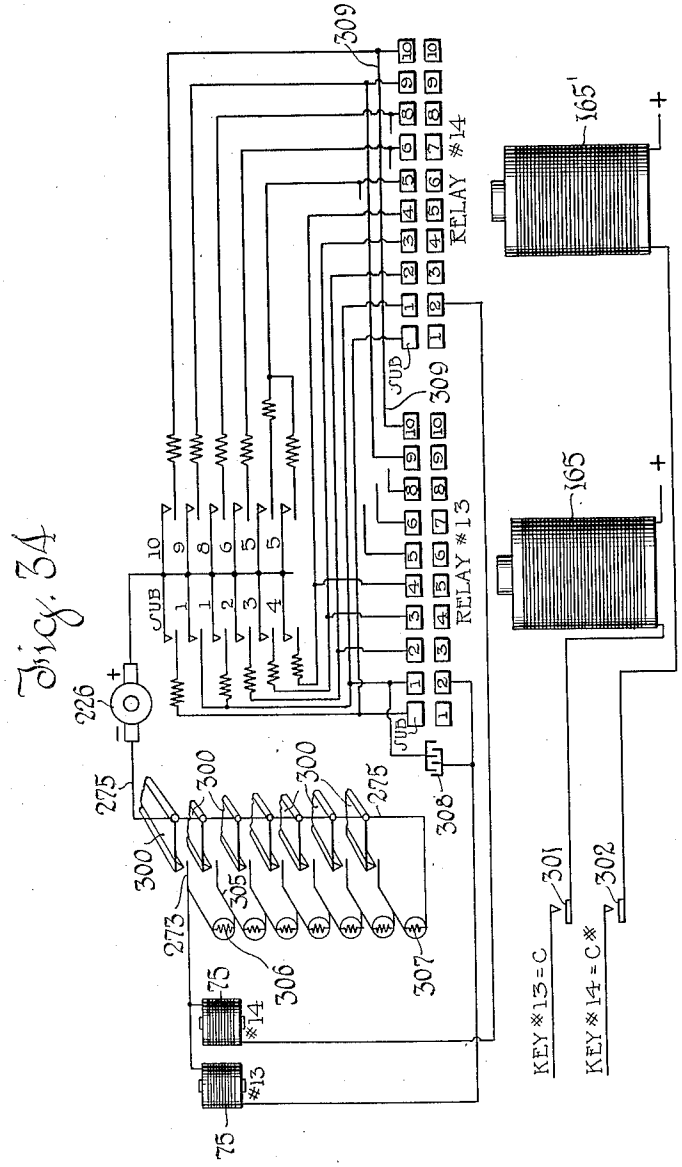


Fig. 34

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Fig. 36

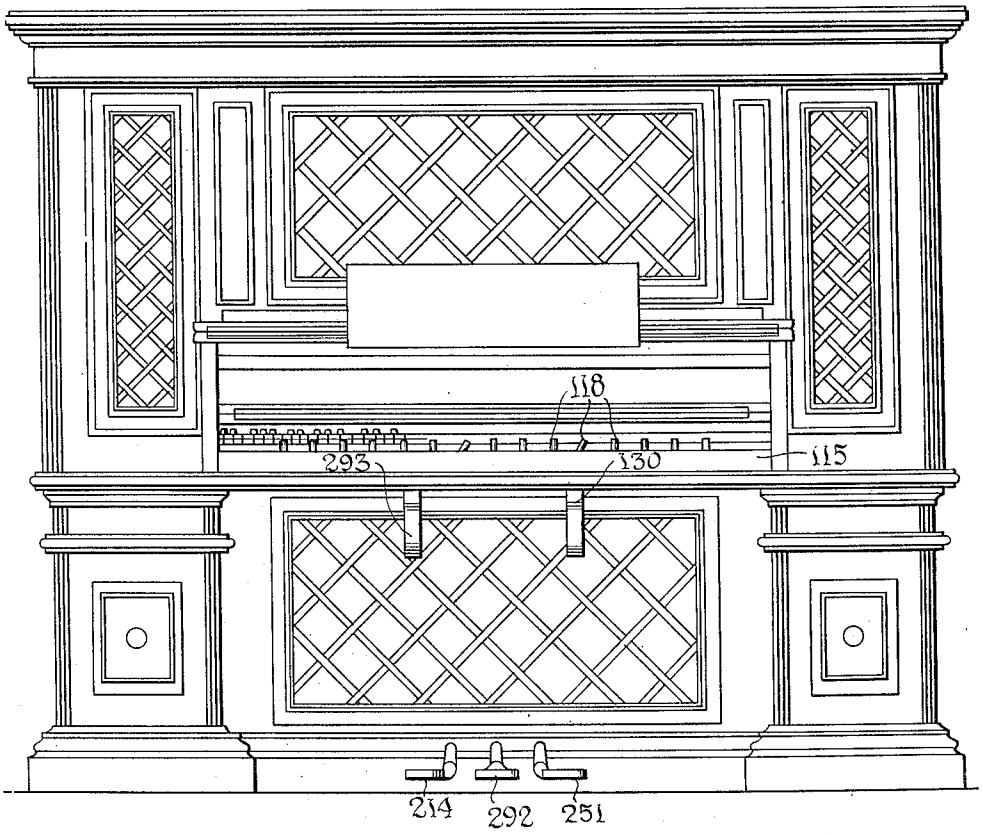
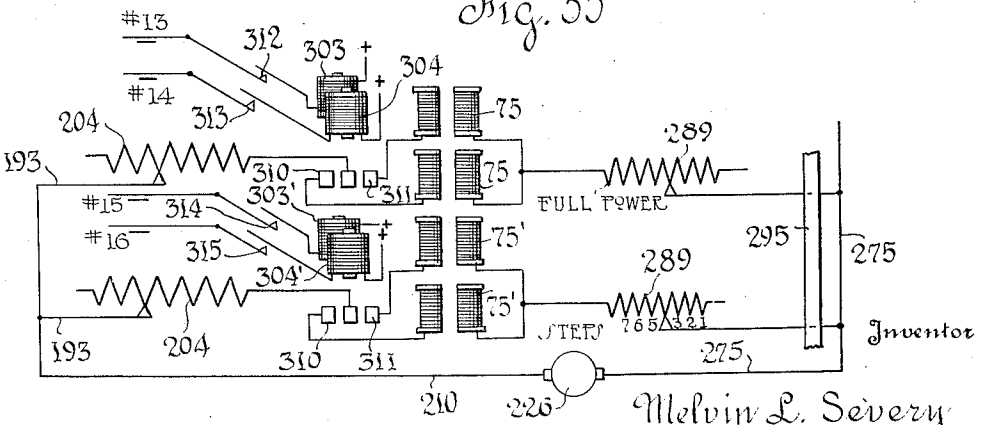


Fig. 35



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Patented Feb. 28, 1933 1,899,884

UNITED STATES PATENT OFFICE

MELVIN L. SEVERY, OF LOS ANGELES, CALIFORNIA, ASSIGNOR TO THE VOCALSEVRO COMPANY, OF LOS ANGELES, CALIFORNIA, A CORPORATION OF DELAWARE

ELECTRICAL MUSICAL INSTRUMENT

Application filed August 4, 1930. Serial No. 472,969.

This invention relates more particularly to a musical instrument having for each of the various pitches of its range or gamut, one or more qualities of tone, each note of given quality being derived from magnetic undulations set up by a moving member, or moving members, provided with wave-producing means. Each of said members is adapted, through co-acting mechanism, to produce at the requisite loudness one of the partials composing the particular note desired, and all the said members are adapted to produce, at their proper relative loudnesses, air vibrations representing all the desired partials of the said tone. These synthesized air vibrations are impressed upon the ear as a tone of the predetermined pitch and quality desired.

An important object of this invention is the production of a relatively small, cheap, and compact musical instrument adapted to produce any desirable musical qualities of tone, orchestral, vocal, or other, and to grade and control the same at will so that a true vocal or orchestral effect may be attained.

Another object of the invention is to provide, in the cheaper grades of the instrument, a means for giving the necessary separate expression to the air and to the accompaniment of a musical selection, through the instrumentality of a single key-manual.

Another object of the invention is to provide sensibly fundamental tones having the eighty-four pitches associated with a seven octave scale tuned in equal temperament, the same eighty-four notes being used not only for the pitch-giving primes of all of the notes of the instrument, but also, suitably proportioned as to loudness, for all of the other partials which produce the many varied qualities or timbres of the instrument. This is what I denominate my "borrowing system", and I use it here because of its extreme simplicity and cheapness of construction, coupled with a musical efficiency remarkable in so small and inexpensive an instrument. In more elaborate instruments, however, I prefer to use a non-borrowing system wherein the sounders used as primes are not at the same time used as upper partials, such practice assuring an even greater musical excellence although it is relatively more expensive and complex.

A still further object of the invention is the production of an instrument requiring no tuning and practically no up-keep, the parts being simple, durable and inexpensive.

In musical instruments making use of a scale tuned in equal temperament and depending for the musical pitches of such scale upon rotating members producing pulsations, all such pulsations, including those representing the well-known incommensurate ratios subsisting between certain notes of each octave, can be secured with an accuracy sufficient for all practical purposes by the employment of six rotating shafts or cylinders for an instrument having a range of seven octaves. More rotating shafts may be used, and I have in some cases used twelve, but for simplicity and cheapness I prefer the smallest feasible number of moving shafts. For this reason I make use of the plan clearly set forth in U. S. Patent No. 1,167,663 granted to G. B. Sinclair and G. I. Fiske, and dated January 11, 1916.

As shown herein the invention is embodied in a series of six correctly timed cylindrical rotors or shafts carrying members or timbre-forms adapted, with their coacting parts, to produce eighty-four sensibly fundamental tones having the pitches of the notes of seven octaves of the tempered scale. To this end, as will be seen by reference to the aforesaid Patent No. 1,167,663, all my said timbre-forms, like the commutators therein shown, are constructed to produce either sixteen, seventeen, eighteen or nineteen vibrations per revolution, or some multiple thereof.

In the drawings:

Fig. 1 is a front elevation of the more essential parts of an instrument constructed in accordance with this invention;

Fig. 2 is a plan view of the essential portions of the mechanism shown in the lower part of Fig. 1;

Fig. 3 is a front elevation of a soundboard and associated parts;

Fig. 4 is a sectional view on the line IV—IV of Fig. 3;

Fig. 5 is a similar view on the line V—V of Fig. 3;

Fig. 6 is a detail view showing the mechanism for attaching magnet-cores to bridges associated with wooden amplifiers of considerable thickness, and for adjusting said cores;

Fig. 7 is a detail view, taken at right angles to Fig. 6, showing a variant form of mechanism for attaching magnet-cores to amplifiers of metal which are relatively thin;

Fig. 8 is an enlarged end view of a dentated magnet core, showing also the supporting elastic spider therefor;

Fig. 9 is a plan view of a portion of a sixteen-toothed member or timbre-form;

Fig. 10 is a plan view of a portion of another type of sixteen-toothed timbre-form;

Fig. 11 is a side elevation of a key of the key-manual and some of its associated parts;

Fig. 12 is a plan view showing a detail of the contact block of Fig. 11;

Fig. 13 is a detail view showing the adjustable, flat, contacting member of Fig. 11;

Fig. 14 is a sectional end view of the tappet-rail of the instrument;

Fig. 15 is a front view showing the more essential details of a portion of the tappet-rail;

Fig. 16 is a detail view from above, of the tappet contact finger block of Fig. 15;

Fig. 17 is a detail view of the part 126 of Fig. 15;

Fig. 18 is a diagrammatic view of the tremolo mechanism;

Fig. 19 is a face view of a portion of the multi-pointed relay system;

Fig. 20 is an end view showing the essentials of a single relay-unit, the obstructing panel being removed;

Fig. 21 is a front elevation of the relay system of Fig. 19;

Fig. 22 is an end elevation of a double type of relay which permits certain economies in construction;

Fig. 23 is a rear elevation of certain parts of said relay;

Fig. 24 is a plan view showing the essential parts of a single multi-fingered partial-rocker;

Fig. 25 is an end elevation of certain details of the partial-rocker mechanism;

Fig. 26 is a rear elevation showing the manner of stacking the multi-fingered partial rockers seen in Fig. 24;

Fig. 27 is a side elevation, partly diagrammatic, showing the pedal expression-control;

Fig. 28 is a rear view of said expression-control, showing the two multi-contact pedal sections, their coacting brushes, and the disposition of the pedal rods of the three pedals;

Fig. 29 is a diagrammatic view of the switching system for placing the bass and the treble portions of the key-board under control of separate pedals, at will, or controlling both sections by either pedal;

Fig. 30 is an end elevation of part of the multi-fingered resistance-system actuated by the pedals, showing the relation of the stacked switches of one of the two units or groupings thereof;

Fig. 31 is a front elevation of a portion of said resistance-system;

Fig. 32 is a partial plan view showing more clearly certain portions of said resistance-system;

Fig. 33 is a wiring diagram showing the electrical placement of the various parts of the instrument in a manner which enables the circuits to be readily traced;

Fig. 34 is a diagrammatic view likewise showing the electric circuits for various parts of the instrument;

Fig. 35 is another diagrammatic view of certain electric circuits including both the operative and the speaking system as in the case of Fig. 34;

Fig. 36 is a front elevation of the instrument showing the placement of pedals, knee-swells, tappets, etc.

As is well known in scientific music, the quality of a musical tone, or its timbre, is dependent upon its component partials and their relative prominence. These partials normally are, to all intents and purposes, whole-number multiples of that particular partial among them known as the prime or pitch-determining partial of the tone. It is not so commonly known, however, that a seven-octave instrument tuned in equal temperament has all the partial vibrational numbers to and beyond those partials which are of any especial importance in the production of musical tone-qualities, represented to a degree of perfection quite sufficient for all practical purposes. Therefore, by producing, combining, and controlling at will eighty-four fundamental tones, used for primes and all other partials, I am able to produce all desired musical timbres with a simplicity of mechanism which is indeed remarkable.

The first six partials are those which are important in musical timbres, but in this instrument I use to and including the tenth, taking, however, a sub-octave in place of the seventh partial, as I have found a graded lower octave more useful than the seventh partial. I do not, of course, limit myself to any particular number of partials, but the number here used gives most excellent results for an instrument of this capacity. Neither do I limit myself to the number of partial gradations herein shown, as the more varieties of strength each partial has, the greater the number of tone qualities possible to the instrument. It is merely a matter of expense. It is desirable that each important partial should have at least two to three dif-

ferent loudnesses, but in most cases I have not here illustrated so many lest the wiring be too complex to be easily understood.

The eighty-four simple tones to which I refer in connection with this invention are produced as set forth in Letters Patent No. 1,464,729 granted to me August 14, 1923, the pulsation-producing members, whether each be integral or laminated, educing in the present instance, only one periodicity characterizing a simple or fundamental tone.

Inasmuch as the pressure of a key of the key-manual does not directly actuate the tone-producing magnet, such magnet being operated through its associated relay, I find it convenient, for more ready comprehension, to divide the instrument into two main systems designated respectively "the operative system" and "the speaking system", the key-manual of course belonging to the former system, and shall describe the same in the order mentioned.

The more essential moving parts of the instrument with their co-acting members are shown in Fig. 1, the belting and some other details being omitted to avoid confusion. In said figure the numeral 1 designates one of the three rotor-carrying cylinders or shafts of the bass section of the instrument, this shaft being associated with all of the notes G#, A, A# and B of the lower three octaves of the instrument's compass. Similarly, 2 designates one of the three treble cylinders or shafts, that shown being the one associated with the same notes of the four higher octaves of the instrument's compass. Pulleys 3 and 4 of like size are provided for driving said shafts. Sound-boards 5 similar to those of Figs. 3, 4 and 5 are each provided with magnet-rails 6 from which magnet-cores 7 are seen protruding in co-action with their respective pulsation-producing members 8. Openings 9 between the sound-boards of the bass section of the instrument (Figs. 1, 4 and 5) serve, in the case of each pair of boards, to ventilate the chamber between them and release the sound-waves created therein, the bass section of the instrument carrying in each frame two parallel boards as more clearly shown in Figs. 3, 4 and 5. The sound-boards 5 are mounted in slidable frames 10, the frames being normally fastened together as at 11 so that they may slide as a double unit in runways 12 provided for that purpose and for holding the boards securely in position. The six shafts or cylinders such as 1 and 2 are each stepped upon a ball at their lower ends, and are each surrounded there by a ball-bearing indicated at 13, while similar ball bearings serve the upper ends of said shafts as indicated at 14. To quiet the slight noise of the moving parts, they are placed at the bottom of the instrument as shown, a sound-deadening partition 15 formed in sections so that it may be easily removed when desired, being also provided. The two wider sections of this partition between the bass and treble sections, and the narrower end sections 15^a, 15^a, separate the driving mechanism from the music-producing section of the instrument, which is directly above said mechanism. On either side of each set of three shafts is one of these narrow removable sections 15^a of said partition, the two sections separating on the center lines of the three shafts, and each carrying half rings of felt adapted to close around the shafts when the co-acting sections are in position, thus leaving the shafts quite free while preventing the escape of sound form below. The two wider sections of the partition are also provided with felt packing further to assist in rendering the portion of the instrument containing the moving parts, sound-proof.

A large pulley 16, twenty inches in diameter in this case, carries upon it a smaller pulley 17, a pulley 18 grooved to receive a round belt being mounted on the pulley 17. The pulley 18 serves to give motion to a pulley 19 associated with the tremolo mechanism, the functioning of all of which will be more clearly set forth hereinafter. As will also be more fully explained later, the function of the large pulley 16 is to reduce the rotative speeds of the three bass shafts to one-quarter that of the speeds of the shafts which control the corresponding notes of the treble sections. The pulley 16 also carries suitable governing apparatus installed within a receptacle 20 (see Fig. 2), coverable to exclude dirt and dust. The source of electric energy 21, switch 22, conducting rings 23 and 24, and brushes 25, 26 render operative a speed-regulating finger later described. As seen in Fig. 2 the pulley driving the middle shaft of each group is out of plane with and underlies or overlaps the smaller pulleys of the proximate shafts, thus permitting close arrangement of the three shafts of each group. This is necessitated by the large diameter of these pulleys, ten inches in the present instance.

As stated, the shafts 1 and 2 are for convenience called by the octave-name of the lowest note they carry, but it is to be borne in mind that each of said shafts carries notes of four octave-names, the G# shaft of the bass section, for example, carrying all of the notes G#, A, A# and B found in the lower thirty-six notes of the key-manual corresponding to what I term the bass section of the instrument. 27 and 28 (Fig. 2) indicate respectively the C-shafts of the bass and treble sections, while 29 and 30 designate the E-shafts of said bass and treble sections. 31 and 32 designate the pulleys for the C-shafts 27 and 28 of the bass and treble sections, these pulleys being ten inches in diameter, while 33 and 34 indicate the pulleys driving the two E-shafts 29 and 30 of said bass and treble sections, the pulleys 33 and 34 being in this

instance 7.9370 inches in diameter. Idlers 35, 36, 37 in the treble section, and 38, 39 in the bass section serve to turn the two belts 40, 41 operating the bass and treble shafts respectively. These belts must be of even thickness, as nearly alike in flexibility as possible, and of the same texture throughout. When made of leather not only should the hair side always be made up into the belt one way, as is customary, but the idlers should be so placed and the belts so planned, that only the one side of the belts ever faces the pulleys, since if the belt keeps shifting from hair-side to flesh-side, these changes will be heard in the tones produced by the instrument. If leather is used for the belts they should be carefully worked down on a miller to exact thickness throughout.

It will be noted that idler 36 is slidable so that it may be adjusted for the purpose of producing and maintaining the requisite tension of the treble belt 40, while idler 38 is similarly adjustable with regard to the belt 41 of the bass section. A motor 42 of 1160 R. P. M. is connected to a speed-regulating mechanism 43 carrying a driving pulley 44 of 4.1810 inches diameter serving to propel the six shafts of the instrument at their proper constant speeds despite line fluctuations of the current. These speeds are approximately as follows in the treble section: For the shaft carrying the notes C, C#, D and D#, 485 R. P. M.; for the shaft carrying the notes E, F, F# and G, 611.0617 R. P. M.; and for the shaft carrying the notes G#, A, A# and B, 769.8895 R. P. M. In the bass section the speed of the shaft carrying the notes C, C#, D and D# is 121.2500 R. P. M.; the speed of the shaft carrying the notes E, F, F# and G is 152.7654 R. P. M.; and the speed of the shaft carrying the notes G#, A, A# and B is 192.4723 R. P. M.

Tracing the path of the treble belt 40 it will be seen that it passes from the top of driving pulley 44 to idler 35, whence it passes about pulley 45 on the treble G# shaft; thence to the rear side of the adjustable idler 36; thence to the front of C-shaft pulley 32; thence to the rear side of idler 37; thence to the front of the E-shaft pulley 34; from the rear of said pulley 34 to the rear of pully 16; and from said pulley 16 to the under side of driving pulley 44, thus completing the circuit. The diameter of the pulleys 45 and 46 is approximately 6.2996 inches. The belt circuit for the bass section of the instrument is as follows: From pulley 17 which is fast to the large pulley 16, belt 41 passes to the further or rear side of the bass G# shaft pulley 46; thence about said pulley 46 and to the front of the adjustable idler 38; thence to the rear of C-shaft pulley 31; thence to the front of idler 39; thence to the rear of bass E-shaft pulley 33; thence about said pulley 33 and back to the front of pulley 17, thus completing its circuit.

The speed-regulating mechanism 43 will not be here described in detail since it forms the subject-matter of my co-pending application Serial No. 371,211 filed June 15, 1929, but it should be stated that it is rendered operative through the agency of a centrifugal member such as disclosed in U. S. Patent No. 1,161,349 issued November 23, 1915 to M. L. Severy and G. B. Sinclair. This centrifugal member is here shown as a flexible contact-finger 47 fastened to a pivoted block 48 and carrying an overhanging portion 49 against which presses an adjusting screw 50 whose function is to regulate the pressure of the flexible contact-finger 47 against its limiting pin 51. The finger 47 has a silver or tungsten tip which is adapted in action to contact with the resistably rotatable silver disk 52, the angular position of which may be changed should any pitting thereof occur. This speed-controlling apparatus is, as stated, contained in the receptacle 20. The contact members 47 and 52 are insulated from each other and both are preferably insulated from the frame, but one at least of said members must always be so insulated. I have shown them both insulated from the large pulley 16 and therefore from the frame, as this procedure renders accidental short circuits less likely. To this end separate brush contacts 25 and 26 are provided for each polarity of the current, as seen in Fig. 1. From the negative pole of current-source 21 a wire connects with flexible contact-finger 47, and when the speed of pulley 16 rises sufficiently to move said finger 47 into contact with disk 52, the current passes through said wire and a wire 53 to one pole of a relay-magnet 54. The circuit as shown in Fig. 2 omits the conducting rings 23 and 24 and their co-acting brushes 25, 26 shown in Fig. 1. From the other pole of relay-magnet 54 a wire passes to the positive pole of the source of electrical energy 21, thus completing the finger and relay circuit. A wire 56 receives positive current from source 21, which it passes to one pole 57 of the relay switch operated by magnet 54. The other pole 58 of said switch is electrically connected by wire 59 with one pole of an inductive clutch-magnet 60, the other pole of said magnet being carried by the supporting frame 61 and connected by a wire 62 with the negative pole of current-source 21, thus completing the circuit energizing the clutch-magnet 60.

The speed-regulating mechanism 43 contains gears which are so arranged and proportioned that when driving pulley 44 is turning at the predetermined and desired speed, there is little or no motion between these gears. To attain this condition of affairs, however, the clutch-magnet 60 must oppose a resistance to the free motion of the copper disk or

annulus 63. This occurs without physical contact between magnet 60 and the disk, each time said clutch-magnet is energized by the opening of the contacts in the finger-box 20 carried by pulley 16. This action deenergizes relay magnet 54, permitting the spring-actuated closure of the relay points and the energizing of the clutch-magnet, with the result aforesaid. If the copper annulus 63 is prevented from rotating, the mechanism will speed up materially beyond its requisite velocity, and if it is allowed to revolve without hindrance, the speed of the mechanism will fall materially below the necessary velocity. The finger 47 being, however, exceedingly sensitive to speed changes, a practically uniform and correct speed is maintained even when the motor speed varies, and this without any appreciable movement of the contained gear-mechanism. I sometimes employ a steady, inductive breaking action upon the copper annulus, in addition to the intermittently acting clutch-magnet, where I find it desirable to make the clutch magnet act through a narrower range of speeds, but as this in no way changes the principle of action of the speed-regulator, I have not shown it. Moreover, this mechanism is described in detail in my co-pending application before noted.

The sound-board 5 shown in Fig. 3 is suitably ribbed on both its surfaces (see Fig. 5), and beneath it is another board, not visible, but which is actuated by amplifiers 64, 65 and 66 through the agency of bridge-blocks 67 projecting upwardly through the openings in the upper board. These three amplifiers, bridge-blocks, and lower invisible board serve three notes of the lowest octave of the instrument. All of the notes of this octave are of less than sixty-four vibrations per second, and so require a relatively thin board for the best results. The amplifiers 64, 65 and 66 are of wood and their front ends are secured by dowels to their associated bridge-blocks, their rear ends being flexibly doweled to a block supported rigidly by a casting 68 or 69, as the case may be, the castings 68 being secured to the top and bottom, respectively, of the sound-board frame, while the casting 69 is secured to the sides of said frame and forms a free strut across the active portion of the sound-board somewhat below its median line. Metal amplifiers 70, their front ends screwed to bridge blocks upon the board 5 and their rear ends securely fastened to castings 68 or 69, serve notes above the lowest octave of the instrument.

The magnet-rails 6 are adapted to receive magnets in the openings shown in Fig. 4. These rails, in this case, will each house three speaking magnets, a magnet in each rail serving one of the amplifiers 64, 65 or 66 to which it is opposed, and the remaining magnets of each rail serving the amplifiers 70 associated with said magnets. The magnet rails are secured at their ends to the vertical sides of the board frames, as more clearly shown in Fig. 5. 71 indicates the sound-board before referred to, serving the notes of the lowest octave of the instrument, this board being much thinner than the board 5. The board 71 is also ribbed on both sides (see Fig. 5), and provided on its inner side with the bridge-blocks 67 reaching upwardly through the thicker sound-board to take the operating dowels of the bass amplifiers 64, 65 and 66. These bridge-blocks are shown securely glued to the base board 71 between ribs from which they secure additional attachment (see Fig. 4). Wooden blocks 72, preferably of maple and securely fastened to the castings 68, each receive the two flexible dowels extending down into it from the rear end of its associated bass amplifier, thus permitting the magnet-cores 7 of Figs. 1 and 5, which in practice pass through the openings 73, to deliver their impetus through the bridge-blocks to the bass board 71. The mounting and action of the amplifiers 70 serving notes above the lowest octave of the instrument is similar to that just described. A bridge-block 74 secured between ribs of the upper board has the curved front end of said amplifier secured to it. This amplifier is shown as wavy, and the curve at its outer end where it is screwed to its bridge-block, gives it the required freedom of movement. These metal amplifiers should be made progressively weaker or more flexible, from their rear to their front ends, either by progressive decrease in width, in thickness, or both. The wave-form of the amplifiers is convenient but not essential.

Three speaking magnets 75 are shown in Fig. 5 housed within one of the magnet-rails 6, said rail being screwed at each end to the board-frame. As seen in this figure the magnet-cores 7 have their lower ends fastened to flexible spiders 77, and extend upwardly and freely through a central tube in each helix of wire, said cores being in practice, though not so shown in Fig. 5, secured at their upper ends to their respective amplifiers by means more clearly illustrated in Figs. 6 and 7. For the purpose of more clearly showing the windows and ledges 77′ of the median strut or casting 69 which is adapted to accommodate the metal amplifiers of the horizontally median section of the upper board, the amplifiers 70 are not seen in Fig. 5 and the magnet-cores 7 are broken off at their upper ends. A jack-knife switch 78 is adapted to make and break electrical connection with all the magnets of its board-frame, nine in number in this case. 79 indicates a segment of a revolving rotor showing its relation to the dentated core above it. While the instrument here shown employs a sounding-board form of resonating member, it is to be understood that the invention is not limited

thereto, or to any particular type, as any suitable sound enlarger or resonator may be used, one of the very best forms of resonator being that making use of a more or less confined definite volume of air carefully adapted to the pitch it serves.

Figs. 6 and 7 show details of the mechanism for attaching the amplifiers to their actuating magnet-cores 7, Fig. 6 illustrating a wooden bass amplifier 80 of considerable thickness. A flexible tongue 81 of metal is pinned and soldered firmly into the upper end of core 7 so that it will not rattle. To the upper end of flexible tongue 81 is secured a threaded member 82, also pinned and soldered. A shouldered nut 83, longitudinally slotted as shown at 84 to receive a pin 85 permitting longitudinal but not rotative motion, is threaded upon the member 82. Pin 85 is carried by thumb-wheel 86, said wheel serving to turn nut 83 rotatively while permitting its free movement longitudinally. This arrangement affords easy adjustment of the magnet-core to and from its co-acting rotor without disturbing the amplifier's correct relation to its board, an operation which permits excellent voicing of the instrument. A metallic plate 87 is screwed to the wooden amplifier 80, a retaining nut 88 serving to maintain adjustments when once made. To change the distance of any magnet-core 7 from its rotor, nut 88 is slightly loosened so as to take the pressure off thumb-wheel 86 which is then turned to the required position for the desired adjustment, after which nut 88 is again tightened to maintain that position. The spiders 77 at the lower ends of the cores prevent rotation of said cores.

Fig. 7 shows a variant form of the attachment illustrated in Fig. 6, adapted to the metal type of amplifiers used for notes above the lowest octave, the flexible tongue 81 (viewed in this case at right angles to the position of Fig. 6), threaded member 82 and retaining nut 88 being identical with the parts of Fig. 6. A shouldered member 89 with a free unthreaded hole is securely fastened to the metal amplifier 70, and below this member is a threaded thumb-wheel 90. To make an adjustment the retaining nut 88 is loosened and the thumb-wheel 90 turned one way or the other, as the case may be, thereby permitting the core 7 to take a somewhat different position, after which the nut 88 is tightened to maintain the new adjustment. The function of the flexible tongue 81 is to permit the free movement of the amplifier during its vibration, as a core held against transverse movement by both amplifier and spider would be seriously hampered in its longitudinal activity.

In U. S. Patent No. 1,464,729 granted to me August 14, 1923, I show a core of a speaking magnet adjustably fastened directly to the bridge of a sound-board, and I could adopt such procedure in this instance in cases where a tone of special brilliance is desired. Usually, however, I prefer the arrangement shown in Figs. 3, 4, 5, 6 and 7, in which the amplifiers, of whichever type used, materially round the shape of the wave, making it less brilliant and more pleasing to the ear. Where the weight of the core, added to that of the amplifier, does not secure this effect to a sufficient degree, I sometimes add a further weight, as a lead washer 91 (Fig. 7), located at any suitable point along the length of the amplifier. I also use this same method at times when the amplifier system is found to be too rigid for the best results, and I wish to make it plain that I consider all these and equivalent expedients quite within the scope of my invention.

The construction of the spider 77 shown in Fig. 5 is illustrated in Fig. 8, where 92 designates the enlarged, double-toothed head of a magnet core to which the central disk 93 of the four-armed spider is securely fastened, the extremities of its arms being secured to a larger disk 94. In practice the disk 94 is centrally disposed over its associated speaking magnet 75, and is suitably secured to the magnet-rail 6 housing the same, as shown in Fig. 5. It will be noted that the magnet-head 92 has a space between its teeth much greater than the width of a tooth, and the rotor segment 8 shown in Fig. 9 illustrates a similar characteristic with regard to its teeth and the core-head opposed to them.

The sixteen-toothed pulsation-producing member or rotor 8 is shown in detail in Fig. 9, where a segmental portion thereof is seen having all the teeth except the right-hand one designated 8^a shown alike. This odd tooth, unlike its companions, has its radially outermost surface either flat as shown, or concentric with the center of the rotor, while the outermost surfaces of the remaining teeth form arcs of a much smaller circle. A double-toothed magnet-head 95 is opposed to the member 8, the centers of its teeth being the same distance apart as the teeth of the segment 8. The outer ends of the teeth of magnet-head 95 are shown as having almost the same curvature as the circumference of the pulsation-producing member or rotor opposed to them. This arrangement secures an attraction and let-go of the magnet-core making for brilliancy of utterance and sharpness of articulation, characteristics not favored by any magnetic hold-over. The type of tooth shown at 8^a yields a slightly different result, yet one that may be useful in some cases. It is to be remembered that so long as a key of the manual is pressed its associated speaking magnet is normally energized, so that lines of force are streaming toward both the teeth and the spaces of an opposed member or rotor. Accordingly, it is desirable that care should be taken to procure a

wide difference in attraction between the passage of a tooth and that of a space, in the case of a single-toothed core, or between the passage of teeth and spaces in the case of a multi-toothed core. In the higher octaves where the teeth are fine and the spaces necessarily somewhat small, it is possible to use as many as five or six core-teeth, spacing them as before and materially farther apart than their own widths, in both rotor and core-head. Indeed, in the very highest notes, the teeth of both cores and rotors may be relatively sharp at their outer edges. This use of multiple core-teeth and the somewhat wide spacing of all teeth, is a most vital matter where maximum efficiency and brilliancy are desired. It will be noted that the outermost portions of the teeth of multi-toothed core-heads such as 95 preferably fall in an arc of practically the same circumference as that characterizing the similar portions of the pulsation-producing member or rotor, thus making for maximum efficiency by permitting more intimate co-action between rotor and core without danger of contact.

Fig. 10 shows a segmental portion of a sixteen-toothed pulsation-producing member or rotor 8^b adapted to produce a graver and less brilliant type of tone than that characterizing the rotor of Fig. 9. In this instance the let-go of the rotor teeth is more gradual and less complete than shown in Fig. 9, with the result that the tone is smoother and less insistent. I have shown these two widely divergent types, but it is to be understood that I do not confine myself to either of them, for I may use anything between them as particular occasions may demand, or I may still further accentuate the characteristics of either of the rotor segments shown in Figs. 9 and 10, for I have complete command of the form of the wave produced in the air, as well as of its loudness, its pitch, and all of the functions associated with its use as a partial in a compound tone.

Referring now to Figs. 11, 12 and 13, a portion of the "operative system" as contradistinguished from the "speaking system" will be described. 96 designates a key of the key-manual resting upon the somewhat conventional key-bed, and held in position by the usual vertical pins 96^a passing into broadclothed holes formed in the keys. A projection having a screw-eye passed through it, and an adjusting leather nut, are provided at the rear of each key 96 for the purpose of securing and tensioning a key-elevating spring 97, the lower end of said spring being looped about a slanting, notched dowel 98 glued into the rear of the key-bed. A felted key-strip 99 limits the upward action of the keys under the urgency of spring 97. A multi-contact block 100, seen more in detail in Fig. 12, is screwed to the key-bed beneath each key, the block being conveniently grooved to fit over the longitudinally-extending positioning strip 101. This strip also serves to keep pressed upwardly, in passive position, the wire tongues 102 serving as contact members. 103 designates a wiring-strip, current being supplied through the cable 104. A continuous metal strip 105 serves as a common lead or return, as the case may be, since it is immaterial which purpose it serves, if other conditions are suitably adjusted. A similar contact tongue 102 of each key-block is soldered to the strip 105. The other tongues 102 of key-block 100 are joined to individual wires, which pass into cable 104, said cable being connected with switches and relays later described.

Beneath each key 96 and screwed thereto somewhat forward of its center, is a flexible contact-bridging tongue 106 of metal, seen in perspective in Fig. 13. One end of said tongue is bent downward and shod at its lowermost portion with a strip 107 of silver, adapted to contact, when in action, with the silver tips 102^a at the forward ends of the wire tongues 102. An adjusting screw 108 is passed through each key 96, the lower end of said screw being shouldered or reduced in diameter to pass through a hole in the metal tongue 106, thus serving to hold said tongue against sidewise movement relative to the key. The head of screw 108 is preferably seated in a recess in the upper side of key 96, and the shouldered lower end bears upon the tongue 106, so that upon advancing the screw the shoulder will bear upon and depress the tongue 106. Upon backing the screw the tongue will be permitted to rise by reason of its resilience. The contact wires 102 are bent upwardly at their right-hand ends to facilitate wiring into the cable 104 or on to the continuous strip 105. One similarly disposed wire of each block 100 is joined to said strip. In Fig. 11 this connection is parted to avoid confusion in the drawing, and the open ends thereof being indicated by the wires 109 and 110.

In Fig. 12 the multi-contact block 100 is seen from its under side to show the grooves which extend through somewhat more than half the thickness of said block as seen in Fig. 11, these grooves serving to house and protect the four wire tongues 102 of each block. The under face of each block 100 is provided with a wide transverse groove 111 permitting the block to fit over and snugly embrace the positioning strip 101 common to the series of blocks. This positioning strip causes the wire tongues 102 to lie closely against the upper walls of the longitudinal grooves of the block, and serves to press and hold the upturned ends of the wire tongues 102 in the holes 112 extending through the top of each block 100, as seen in Fig. 11. The longitudinal grooves in contact-block 100 which ap-

pear at its rear end beyond the wide transverse groove 111, have no function and could be dispensed with if the blocks were molded instead of sawn, as might well be the case. A hole 113 receives a screw by which the block 100 is fastened to the key-bed under its appropriate operating key.

It has already been stated that one of the four wire tongues 102 shown as associated with each contact block 100, is connected to the continuous strip 110 used, say, as a return, and this tongue may well be that farthest removed in Fig. 11, or nearest the bass end of the instrument. In this case the next or second of these tongues would be connected by an individual wire through the cable 104, to one pole of the magnet operating the relay bearing the number of the note with which it is itself associated, the other pole of said magnet joining a source of electric energy and the circuit being completed through the common continuous metallic return-strip 105, the leftmost tongue 102, and the contact-bridging tongue 106. In the case of the third wire tongue 102, the purpose of which is to couple up an octave, its connecting wire runs to one pair of contacts of a multiple switch capable of opening or closing the circuits of all these third wire tongues connected to it. From the co-acting contact of this third pair, a wire runs to one pole of the relay magnet bearing a number higher by twelve than that of the manual key with which said third wire tongue is directly associated. From the other pole of this last-named relay magnet the circuit is essentially the same as in the case of the previous or second wire tongue. The last, or fourth wire tongue 102, serves to couple down an octave, for which purpose it is connected by a wire with one contact of the appropriate pair of contacts in a separate couple-down multiple switch essentially like that mentioned for coupling up. From the co-acting member of this fourth pair, a wire runs to the relay magnet bearing a number less by twelve than that of the manual key directly over the fourth wire tongue 102, after which the circuit is substantially as in the similar cases. It will be seen, therefore, that to couple up or couple down an octave requires only the closure of the appropriate multiple switch or circuit-making and breaking device. If this be left open, all its corresponding or associated wire tongues remain dead and inoperative.

Fig. 14 shows a cross section of the tappet-rail forming part of the "speaking system". said rail being seen in its correct placement with regard to the instrument as a whole, in Fig. 36. The two longitudinally split halves of the tappet-rail are indicated at 114 and 115, each portion of said rail being secured to the member 116 by screws. In addition the portion 115 is also secured to the portion 114 at its top at convenient intervals. 117 designates the cylindrical part of the tappet-rocker, the upwardly-projecting radial fingers 118 of which render possible the angular placement of the tappets and the operation of each tappet as an electric switch. A pin 119 driven into the portion 114 of the tappet-rail, and having its other end supported against downward pressure by a ledge 120, serves as a pivot for the rocker 117. 121 designates a tappet contact-finger block in and above which are seen two of its co-acting fingers, the contact-bridging member 122 of Fig. 15 being omitted in Fig. 14 for clearness of illustration. A cable 123 carries the wires of the tappet system.

Fig. 15 shows the tappet-rail of Fig. 14 with the front portion 115 removed to exhibit the interior construction of said rail, and also illustrates the radial contact-bridging fingers 122 omitted from the previous figure. The median line extending from the tip of each finger 122 throughout most of its length on both its front and rear sides, though the latter cannot well be shown in this view, represents a silver wire soldered to said fingers to insure a perfect contact with the co-acting members 124 opposing each other, the fingers 122 passing between said members 124 essentially after the usual manner of the movable member of a jack-knife switch. Broadclothed recesses 125 limit the angular movement of each upwardly-projecting radial finger 118. To make sure that no tappet switch shall remain midway of its course, but shall always stop at one or the other extreme of its movement, a flat metallic member 126, shown in perspective in Fig. 17, has its top end positioned in a groove 127 in the cylindrical part 117 of each tappet-rocker, the other end of member 126 being elastically supported in and by a tongue-spring 128 fastened at one end and bent to slide slightly at the other. By this arrangement the upper end of the metallic member 126 may be swung, although with considerable resistance, first to one and then to the other side of a vertical diameter of the cylindrical part 117 for the purpose already stated. Each contact-finger block 121 carries a plurality of wire contact-fingers 124, the number varying in accordance with the number of partial rockers the particular tappet switch is designed to command. One contact-finger 124 for a return wire is always provided, with at least one additional finger, but there are often many more serving one polarity of as many actuating magnets of the partial rockers later described. These contact-finger blocks 121 are screwed at their ends to the lower part of the front face of the portion 114 of the tappet rail, as clearly indicated in Fig. 15.

Fig. 16 is a view from above of one of the contact-finger blocks 121, showing also in dot-

ted lines the shallow underneath grooves for the angularly bent wire contact-fingers 124. It will be noted that there are eleven holes 129 extending from the top of block 121 down into said grooves, the wires 124 being thrust up into these holes and their bent ends seated in the underneath grooves to prevent their escape when the block is screwed into position. The holes 129 are staggered for the two rows of contact-fingers, said fingers being preferably bent at different angles, first one way and then the other, so that they may all extend toward the front for convenience in attaching them to the cable 123 in Fig. 14.

Fig. 18 shows the tremolo system already adverted to in connection with Figs. 1 and 2. The knee-swell 130, which is the right-hand knee-swell of Fig. 36, is shown in Fig. 18 as passively positioned against a stop 131 by a spring 132 which causes a bifurcated brush 133 having one prong somewhat longer than the other, to rest wholly upon insulation at the right-hand of a resistance-drum 134 which, when the knee-swell is operated, is traversed by the brush 133. Whenever the tremolo is actuated, it introduces into the circiut of all speaking magnets in action, at the will of the player, any desired amount of resistance, while the revolving short-circuiting or shunting commutator 135, driven by a belt passing about the tremolo pulley 19, periodically cuts in and out this inserted resistance, causing a shake in the tone the prominence of which will, for any given passage, depend upon the position of knee-swell 130. The pronged brush 133 is carried by a flat, slidable bar 136 running in graphited felt bushings, said bar having secured to its leftward end a flexible wire connection 137. Another connecting wire 138 is secured to the leftward end of the resistance helix carried by drum 134, this wire 138 being suitably secured to the box containing said drum by a binding post or equivalent means. A link 139 serves to connect bar 136 with the innermost extremity of rod 140. The resistance-shunting commutator 135 comprises three superficial metallic portions 141, 142, 143, the brushes 144 and 145 being each adapted to bear successively upon two of the said superficial metallic portions of said commutator. In the position in which they are shown in Fig. 18 the brushes 144 and 145 are, with respect to the revolvable commutator, insulated from each other, but as soon as the metallic portion 143 comes uppermost the brushes will be electrically connected by the bridging action of this portion of the commutator. This is the condition under which the resistance of drum 134 is shunted out during the operation of the tremolo, at each half revolution of commutator 135, while during the other half revolution the current is forced to pass through that portion of the resistance helix which is not cut out by the movement of brush 133 to the left. The manual keys are indicated at 96 and the speaking magnets at 75, it being understood that in the diagrammatic showing of Fig. 18 all possible irrelevant parts are omitted and only the tremolo system illustrated.

A flexible contact spring 146 (Fig. 18) is secured to the left end of the box which houses the resistance drum 134, the left end of the resistance helix and of wire 138 being secured to said contact spring. To ensure perfect and correctly timed contact, the contacting end of spring 146 is adjusted relative to its co-acting contact by a screw 147 passed through an opening in the spring. An angularly bent member 148 is secured to the slidable bar 136, and pushes the flexible tongue 146 slightly to the right as member 148 contacts with said tongue under the action of the knee-swell spring 132, thus shutting off the tremolo upon the removal of the player's knee and cutting out the resistance helix irrespective of the position of the revolving tremolo commutator. As shown in Fig. 18 the tremolo is not in action, and the current passes from source 149 to the key 96 associated with the leftmost of the five speaking magnets 75; thence from the other pole of said magnet by a wire 150 to wire 138; thence to contact spring 146, contact member 148 and wire 137 back to said source 149.

If, now, the knee-swell be moved to the right, brush 133 will come into contact with the resistance helix, the contact members 146, 148 will open, and the circuit will be as follows with the revolving commutator as shown: From the source of current 149 as before, to and through the leftmost of the five speaking magnets 75 and wire 150 to wire 138, since the commutator brushes 144, 145 are open-circuited; thence by such portion of the resistance helix as is in circuit, to brush 133, slidable bar 136 and wire 137 back to source 149. When, however, as occurs a fraction of a second later, the tremolo commutator makes a half revolution bringing the bridging member 143 under the brushes 144, 145, the resistance helix is immediately cut out, as will be obvious. Two very important advantages inhere in this system. First, the tremolo may be instantly operated for even a single note without the use of the hands; and second, it may be used with any desired degree of prominence, there being many cases where a slight tremolo is excellent but a pronounced one would be very undesirable, while at other times a marked tremolo is quite permissible. So far as I am aware, this gradable tremolo is a new and valuable feature in an instrument of the character here disclosed.

Figs. 19 and 20 are respectively a face and an end view of a portion of a row of single relays. When of the type here shown these relays are commonly assembled in six rows, with seven relays in each unit. Two of these

units, therefore, contain the eighty-four relays serving the eighty-four notes of a seven octave instrument, and it is to be borne in mind that the relays bear the same numbers as the notes of the manual with which they are most commonly associated. Thus note #1 of the manual serves to elicit the C of 32.331 vibrations, the succeeding notes being numbered in order to and including note #84 of the manual, which serves to elicit B of 3906.168 vibrations per second. One of the wooden strips 151 upon which are mounted the seven magnets of each row of relays is illustrated in part in Fig. 19. Each relay magnet comprises a core 152 provided with a co-acting swinging armature 153 to which is attached a flexible strip 154 serving to rock the member 155, thus bringing into electrical contact the front and back rows of ten co-acting pairs of tongues 156, 157. A continuous upstanding strip 158 is provided in one surface, at its upper end, with a rabbet-like recess in which is glued a strip of cushioning felt 158^a, against which the rear contact-carrying tongues 157 may press in action. The upper magnet head 159 is four-sided and of fiber, the somewhat oblique head of the magnet-core 152 projecting therethrough. Three small perforations 160 are provided for wiring the magnets, the wires being attached to ears 161 secured to the fiber head 159 by rivets 162. A portion of one of the side strips or cheeks is seen at 163, and serves to connect in one unit the six rows of seven magnets each, the base of each relay being fastened to the wooden strip 151 by screws 164.

165 (Fig. 20) indicates the helix of the relay magnets seen in Fig. 19, the rear end of core 152 being riveted to a metal plate 166 screwed to the wooden strip 151. This plate serves to secure the relay magnets in position, and also acts as a fulcrum for the lower end of the swinging armature 153. The two curved tongues 167 of armature 153 (shown by dotted lines in Figs. 20 and 21) are passed loosely through holes in plate 166 just above the rabbet-like recess formed in the wooden strip 151 to house said tongues without interfering with their free motion as the armature swings. As stated, the flexible strip 154 is secured to the upper end of armature 153, the other end of said strip 154 being secured to the rocking member 155 which is hinged at 168 between upstanding ears 169, shown more clearly in Fig. 21. A longitudinally extending member 170 (Figs. 19 and 20), of hard rubber or other non-conductor of electricity, is secured to the rocking member 155, and serves to press the associated front tongues 156 (ten in number) into contact with their respective co-acting rear tongues 157 whenever the associated relay magnet is energized. A longitudinal recess 171 (Fig. 20) is provided to receive the actuating wires for the relay magnets, wiring strips 172 being likewise provided for the relay contact tongues. A substantial insulating strip 173 is inserted between the two sets of tongues 156, 157, and as these tongues are commonly bradded to the respective supporting strips 158 and 174, I provide on either side of this strip a soft material in which the heads of the brads may nest.

As seen in Fig. 21 the upstanding ears 169 are formed by the bent-up ends of a metallic strip secured to the continuous strip 174 by screws 175, this strip 174 being held in place by the panel 163. The spaces between the relays are also utilized for securing the parts 151, 158 and 174 together at intermediate points. The dotted line below the armature-tongues 167 in Fig. 21 indicates the bottom of the recess in the continuous strip 151. Holes 176 in the lower ends of the relay tongues are convenient for wiring, and a portion of the wiring strip 172 associated with them is broken away in Fig. 21 in order to show said tongues.

I have described this system as based on the relay shown most clearly in Fig. 20, not only for the reason that it is a very serviceable type in certain cases, but for the more cogent reason that this single-type relay lends itself more easily to explanation than does the double-type shown in Figs. 22 and 23, the construction and action of which will be more readily understood after describing the single type. I do not limit myself to either type, each having its proper place. I have shown the grouping as applied to the single-type because it can be more easily explained, and is the best possible approach to an understanding of the functions of the double-type relay.

Figs. 22 and 23 illustrate a double type of relay adapted to serve two notes standing to each other in the relation of seconds on the key-manual, as notes number one and two, three and four, five and six, etc. This relay is essentially two single relays put together, but in this instance a single row of center contact tongues replaces the two rows of outside tongues, as will be duly explained. As will be shown in connection with Fig. 34 where relays #13 and #14 are shown as of the single type, the upper rows of contacts of each relay have their similarly numbered tongues wired together, and this double type of relay takes advantage of that fact to make one row of contacts serve instead of two rows. Since seconds are seldom played together and are dissonant when so played, it is advantageous rather than harmful to play both of said notes simultaneously through the one resistance, thus somewhat mollifying the effect.

In Fig. 22 the magnets are of the form already described, the plates 166 supporting the magnets being in this case bent at a right angle in order to secure them to the continuous

members 177. The swinging armatures 153, which are loosely fulcrumed at their lower ends in the plates 166, have links 178 at their upper ends for flexibly attaching them to the rocking, brush-actuating members 155, said members being hinged between the ears formed out of and upstanding from the plates 166 as before stated. Seated and made fast in depressions extending across the brush-actuating members 155 are small non-conducting rubber tubes or rods 179 (Figs. 22 and 23), said rods serving to press their co-acting tongue-contacts 180 against the interposed central contacts 181. The metal tongues 180 are seated in shallow saw kerfs formed in non-conducting molded or wooden strips 182, each of said strips being further provided with a longitudinally extending groove 183. Each of the tongues 180 has a protuberance 184 conveniently made in the form of a short bend, to enter the proximate groove 183 and thereby prevent vertical movement of the tongues. The tongues 180 are held permanently in place between the strips 177 and the opposed strips 182, and are fastened together with screws, or by glue, or in any other suitable way. The central row 181 of metal tongues is similarly positioned and held between the members 182, one of said members being provided with the aforementioned saw kerfs and grooves 183 to assist in the proper placement of said tongues before they are permanently secured. The upper ends of strips 182 are provided with a rabbeted and felted portion 185, which acts as a damper for the central rows 181 of metallic tongues. 186 indicates wiring strips and 187 the associated cables. All of the metallic tongues are preferably provided with silver contact members at their co-acting surfaces.

The pivotal wire 189 for the rocking brush-actuating member 155 is illustrated in Fig. 23, the rearwardly extending, stamped ears 190 which afford bearings for the bifurcated links 178 of the armatures being also shown at the upper central portion of member 155. As seen in this figure, the bearing ears 169 are formed from the bib-like portion 191 of plate 166, holes 191′ being provided for fastening said plates to the continuous member 177 of Fig. 22. The rubber tubes or non-conducting rods 179 described in connection with Fig. 22 are shown more clearly in this figure.

Fig. 24 is a view, partly in section of one of the stacked members of the partial-mixing system, looked at from above, and showing the contact tongues 192 and the continuous, co-acting, silver-tipped rocking member 193. The contact tongues 192 are secured between continuous strips 194 and 195 of non-conducting material, as set forth in connection with the double relay illustrated in Fig. 22, the strips 195 being seen in Fig. 25. Bosses 196′ on the castings 196 serve to connect the parts firmly together, these bosses being best seen in Fig. 26. A solenoid magnet 197 operates the continuous rocking member 193, said member swinging upwardly when magnet 197 is actuated, and coming into contact with all the co-acting tongues 192 above and close to it. This solenoid 197 is provided with a central thin tube of non-magnetic material, in which the plunger 198 of magnetic material freely moves in action. A core-like plug 199 of magnetic material is pressed into the central tube of the solenoid and through the metallic yoke 200 at the bottom of the magnet, as shown. The plug 199 enters the solenoid for a distance somewhat less than half the length thereof, leaving a free space for the approach of the movable plunger 198 after the well-known manner. A spring 201 keeps plunger 198 passively away from plug 199, and a link 202 freely moving in the slotted head of said plunger, serves to transmit the movement of the plunger to the continuous rocking member 193 whenever the solenoid magnet 197 is energized.

An adjustable, felted, sliding stop 203 is screwed to the casting 196 beneath the boss 196′ (see Figs. 24 and 26), and serves to limit the downward movement of the continuous rocking member 193 when magnet 197 is de-energized. Resistance bobbins 204 (Fig. 24) are each connected at one end to one of the contact tongues 192, the other ends of the wires of each bobbin being forked as shown at 205 for the purpose of serving adjacent note numbers of the manual, as heretofore explained. The connections to these forked wires will be described later. The pivoted ends 206 of the rocking members 193 are shown in Figs. 24 and 25, the extensions 207 which serve as bearings for the ends of the bobbin-bearing rod 208 being shown broken away in Fig. 24. The continuous wooden member 209 (Figs. 24 and 25) is felted along two of its surfaces, the upper felt strip serving as a passive rest for the contact tongues 192, and the other felt strip acting as a bumper for the rocking member 193. A conducting wire 210 is attached to the rocking member 193 as shown in Fig. 25. This figure also illustrates more clearly the means for spacing and securing the continuous contact-tongue-holding strips 194 and 195, the strip 195 being formed with a thin, longitudinally-extending tongue 195ª to serve as a wiring strip for the ends of the contact tongues just above it.

Fig. 26 is a rear view of several units of the partial-mixing system shown in Figs. 24 and 25, illustrating the method of stacking the same, the resistance bobbins being omitted for clearer showing. 211 indicates the vertical panels which are rabbeted to receive the ends of the various castings, said castings being preferably made of aluminum. This

figure also shows the screws 213 which secure the felted stops 203 in position.

The expression-control or pedal-resistance system of the instrument is illustrated in Figs. 27 and 28, the pedal 214 at the bass end of the instrument being seen in Fig. 27. Standards 215 screwed to the base-board 216 carry the bearing rod 217 serving as a fulcrum for the three arms 218, 218 and 219 associated with the three pedals, said pedals being shown in Fig. 36 in their proper positions in the instrument. The arm 219 is much shorter than the arms 218, and carries a single elongated contact 219′ and conducting strip, the contact 219′ co-acting with two contact-tongues 220, the rear one of which is directly behind and concealed by that here shown. Both of these tongues are supported by but insulated from, the metallic casting 223 and from each other. A source of electricity 226 supplies positive current through the wire 226′, casting 223, flexible tongue 222 and connected strip, to the elongated contact or bridging-bar 219′, so that when this bar is raised into touch with its co-acting contacts 220, 220, said contacts are fed with positive current. From the nearer contact-tongue 220 a wire 225′ extends to the lower pole of rocker-operating magnet 239, while from the further contact-tongue (invisible in Fig. 27), a wire 221′, shown in full line, extends to the lower pole of rocker-operating magnet 239′, thus supplying both of these magnets with positive current. From the source of electricity 226, lines carrying negative current extend directly to the negative poles of both these magnets 239 and 239′, thus completing their circuits.

Since the middle pedal 292 of the instrument is an accent or sforzando pedal (see Fig. 36), it is obvious that it must operate both of the expression-control units at the same instant, and the magnets 239 and 239′, when energized, produce full volume throughout the range of both units, or in other words, throughout the entire instrument. Inasmuch, however, as the player may be operating the two outside pedals when it is desired to introduce such sforzando effects, I have arranged that the left knee-swell 293 (see Figs. 27 and 36) may perform the same function as this central pedal, requiring only to be pressed leftwardly for that purpose. This pressure will bring the contact members 231. 231′ of Fig. 27 into connection with the positive pole of current-source 226, thereby energizing the rocker-operating magnets 239, 239′ of the two expression-control units, the other pole of current-source 226 serving current directly to the other pole of said magnets 239, 239′ as clearly shown.

When, however, the sforzando effect is to be produced by pedal 292 rather than by the knee-swell 293, the path of the current will be that already described, it being understood that the return to passive position of said knee-swell has opened its associated contacts 231, 231′, and that the pressure of the pedal 292 has raised the short central pedal-arm 219 at its inner end, thus bringing its elongated contact 219′, fed with positive current from source 226, in touch with both co-acting contacts 220. When the parts are thus positioned, the sforzando effect will be produced by pedal 292 instead of by knee-swell 293.

The other rocker-operating magnets for the first unit of the expression-control system are indicated at 233, 234, 235, 236, 237 and 238, Fig. 27, while the other operating magnets for the second unit of said system are indicated at 235′, 236′, 237′ and 238′. The connecting wires for the magnets of the second unit are to be understood as running to their appropriate parts of Fig. 28, precisely as will be described in connection with Fig. 27 in regard to the other unit and its associated pedal.

The pedal-arms 218, 218 and 219 are adjustably connected to their respective pedals by turn-buckle members 240, adjusted by nuts 241 (Fig. 27). A spring 242, also adjustable as to tension at its upper end, where it is supported upon the frame as clearly shown, serves to maintain the pedal associated with it passively raised at its outer end. The pedals are hinged in the usual manner to short standards 215′, as shown in connection with pedal 214, Fig. 27. The associated arm 218 of said pedal is broken away at its leftmost end, in order more clearly to show the contact-segment 248 traversed by a pronged brush 243, dotted lines indicating the shape of the broken-away portion of said arm, and a dotted line 244 indicating the electrical unity between brush 243 and the metallic strip 245 which serves, as in the case of the middle pedal-arm, to connect through the metallic casting 223 with the positive pole of current-source 226. As pedal-arm 218 is operated, the brush 243, one prong of which is longer than the other, sweeps progressively over the co-acting insulated contact blocks 246, these blocks being best seen in Fig. 28. This causes the various rocker-operating magnets 233, 234, 235, 236, 237, 238 and 239 to be successively energized in the order named, by upward movement of pedal-arm 218 through the agency of appropriate wires 247 shown in dotted lines in Fig. 27. The contact-bearing segment 248, whose center of curvature is preferably at 217 (Fig. 28), has suitably fastened to it the contact-blocks associated with the resistance systems of the outside pedals 214 and 251 of the instrument, the arms 218, 218 sweeping across said segment 248 relatively near the ends thereof, as clearly shown in Fig. 28. This arrangement necessitates an outrigger type of pronged brush, the pin 249 to which brush 243 is attached, which pin projects from its

arm in parallelism with said arm's axis 217, affording the requisite overhang, and serving at the same time as a metallic conductor of the current.

It is to be borne constantly in mind that the right-hand half of the contact-bearing segment 248 of Fig. 28 and its associated parts are those seen in Fig. 27, and that the rocker-operating magnets 233 to 239 inclusive serve the left-hand or bass pedal 214 controlling the expression of notes numbered 1 to 36 on the manual, while the left-hand half of segment 248 in Fig. 28 is associated with the right-hand pedal 251 (Figs. 29 and 36), serving in a similar manner the treble section of the instrument, or notes numbered 37 to 84 inclusive, in the case of this particular type of instrument. Because of this division of the manual it is to be understood that the left-hand half of the contact-bearing segment 248 of Fig. 28 is associated with a duplicate of rocker-operating magnets 233 to 239 inclusive, for actuating rockers controlling the loudness of the upper or treble section of the instrument. Only the magnets 235′ to 239′ of this duplicate set are shown in Fig. 27, but it is to be understood that the wiring for all of such duplicate set of rocker-operating magnets is similar to that of the magnets for the bass section.

As illustrated diagrammatically in Fig. 29, there are two distinct resistance rocker units, one for the bass and one for the treble, and means to put them at will upon separate outside pedals or to give them both into control of either of these pedals. A wire 252 joins the uppermost contact block of the treble section of segment 248 to the rocker-operating magnet 239′ of said section, this treble section of said segment being controlled as stated, by pedal 251 and its associated brush 251′. Similarly, a wire 254 joins the uppermost contact block of the bass section of segment 248 to one pole of the rocker-operating magnet 239 of said section, which is controlled by pedal 214 and its associated brush 214′. The contact blocks immediately below those just mentioned are associated with magnets 238, 238′ of the bass and treble sections respectively, the other rocker-operating magnets being omitted from this showing as unnecessary. A common return wire 256 is connected to one pole of all of the magnets in both sections, and joins the current-source 226 at its negative pole.

A multiple switch having seven pairs of contacts is provided, and when operated, said switch joins together the wires 252 and 254, one pair of said contacts 257—258 being shown in Fig. 29. A switch 259 placed in any convenient position accessible to the player, when pressed, energizes the multiple-switch actuating magnet 260 which acts upon the armature end of rocking member 261, and causes the other end of said rocking member to press the seven contacts 258 against their seven co-acting contacts 257, thus joining together electrically the wires leading from similarly placed contact blocks of segment 248 controlling the bass and treble sections of the instrument operated through pedals 214 and 251. As shown in the drawings these two sections are independent of each other, and each is actuated by its own pedal. When, however, it is desired to cause either of said pedals 214 or 251 to actuate both sections, or the complete instrument, the switch 259 is pressed, thereby closing the multiple switch indicated by contacts 257, 258. The contact blocks of segment 248 controlling similarly numbered notes in the bass and treble sections of the instrument are thus electrically connected so that either pedal brush 214′ or 251′, if placed on one of said sections, will supply a feed current to both of their associated rocker-operating magnets. In this manner the player may grade the loudness of the entire instrument by the use of either pedal 214 or pedal 251 alone.

Figs. 30, 31 and 32 all pertain to the resistance rocker mechanism forming part of the pedal expression-control system. In Fig. 30 is shown one of the rocker-operating magnets in one of the resistance units, as 233, said magnets being of plunger solenoid type and of usual construction. In this case the unit shown is assumed to be that serving the bass section of the instrument, though the two units may well be practically identical and will be so considered herein despite the fact that a few more contact tongues are used in one unit. A magnetic plunger 262 (Fig. 30) is freely movable in the non-magnetic tube upon which the helix of the solenoid is wound, and to the upper end of said plunger is fastened an upwardly extending, non-magnetic guiding and adjusting rod 263 which passes freely through a magnetic plug 264 pressed into the upper end of the tube upon which the solenoid is wound, the expanded head of this plug being of the same diameter as the heads of the solenoid. The upper end of rod 263 is threaded and carries a felted washer as well as adjusting and check nuts for regulating the stroke of plunger 262.

As seen in Figs. 30 and 31 a longitudinally extending base casting 250 is supported midway of its right-hand portion by a vertical standard 265 which serves to hold the solenoids firmly in position, and assists in binding together the whole stacked structure of the unit. A casting 266, preferably of aluminum, its right-hand end provided with an opening through which the standard 265 passes, is secured by a pin or set-screw 267 against sliding upon said standard. The other end of casting 266 is fastened through openings 268 (see Fig. 32) to a longitudinally extending aluminum casting 269 secured at intervals by screws, one of which is shown,

to the longitudinally extending wooden member 270. Each casting 269 is bent downwardly at its forward end, and is provided at that point with a longitudinally extending wooden strip 271, to the rear of which is screwed a continuous, metallic, conducting angle 272. The under side of each of these angles 272 has soldered or brazed to it a small silver contact bar 272′, positioned to co-act with the silver contacts of the tongue members 273 (Figs. 30, 31 and 32). Wires 274 (Fig. 30) carry the current passing over the angles 272, these wires joining a common wire 275. The lead wires of the rocker-operating magnet 233 are seen at 276, Fig. 30.

A light but rigid arm 277 is pivoted to the lower end of movable plunger 262, its other end being adjustably secured to a longitudinally extending rocking member 278 hinged at its ends through upwardly-projecting ears 279, to metallic plates 280. These plates are screwed to the inner faces of panels 281, and assist in binding together and supporting the whole stacked structure (see Figs. 30 and 31). The arm 277 carries a boss 282 extending across it, and the screws seen on either side of said boss and securing arm 277 to rocking members 278 may, as is obvious, be adjusted to change the angular relation of said arm to the rocking member for purposes of correct adjustment of all the parts to proper working conditions. This rocking member 278 is bent upwardly at its forward end to form a stiffening rib against which may be placed the continuously extending, non-conducting, tongue-lifting bar 283 (Figs. 30 and 31). This bar, when operated, raises all the tongues 273 associated with its stack into contact at their forward ends with the thin silver strip or contacting bar 272′, thus simultaneously putting all the tongues 273 of the stack into electrical connection with the common wire 275. A continuous non-conducting bar 284 of wood or other suitable material, is provided with saw-kerfs or recesses, in which the tongues 273 are securely fastened by brads or otherwise.

The relative placement of the stacks and their approximate vertical distances apart, are shown in Fig. 30 by a suitable repetition of certain of the parts of the lowest stack, it being understood that there will be one less in each unit of these stacks than there are different degrees of loudness in the instrument. The number of stacks beyond seven which may be used, is a mere matter of exceptionally fine gradation, the eight degrees of loudness possible with the seven stacks being ordinarily quite satisfactory. The arrangement of the resistances is best shown in Fig. 34, and will be more fully described in connection therewith.

Fig. 32 shows more clearly the tongue-contacts 273 and the aluminum magnet-supporting casting 266 with its upstanding outside stiffening ribs, an opening in said casting being indicated at 286. Two pairs of speaking magnets, 287, 287 and 288, 288 are shown in this figure, each pair served by a resistance 289. Each of the resistances 289 is joined at the right-hand end to a single contact-tongue 273, illustrating the manner, already adverted to, in which the speaking magnets are joined together in pairs, thus producing tones in the relation to each other of musical seconds, as more fully illustrated in Figs. 33, 34 and 35. The contact-tongues 273 are fastened to their supporting bar 284 by a double row of brads 291.

Fig. 33 illustrates diagrammatically the "speaking" part of the instrument, with only a suggestion of the "operative" system. In this figure the speaking magnets 75 described in connection with Fig. 5 are again shown, each of said magnets having directly associated with it the number of the note of the gamut which it controls. Thus the extreme left-hand magnet 75 in this figure controls note #11, the magnet to the right thereof, note #12, the next magnet to the right, note #13, and so on. Associated with each pair of magnets 75 is a resistance 289 such as seen in Fig. 32 but here shown diagrammatically. A bar 295, assumed in this showing to be movable transversely of its length, affords means for positioning the contact-tongues 273 along the resistance coils 289, thus diagrammatically representing the electrical result attained by the various rockers and their associated resistances which are also shown in the preceding figures. In order to make the mechanical showing clear, the contact tongues in Fig. 33 are designated by the numeral 273 which is applied to the multiple tongues of Figs. 30 and 32, though said tongues are, as to electrical placement and common connection, the equivalent of the silver contacting strip 272′ of the continuous bar 272 of Fig. 30. The reason for this change in the showing in Fig. 33 is obvious, for otherwise it would be difficult if not impossible to suggest an equivalent of the various resistance rockers of the two pedal expression controls. The common wire 275 connecting with the source of current 226 and the wire 210 leading from the opposite pole of said source to the longitudinally continuous rocking members 193, 193′ of the partial-mixing system, are also shown in Fig. 33. The magnets 197 for operating the rocking members 193 (seen also in Fig. 24), are parts of the "operative" system and are only shown here to make the operation of the whole partial-mixing system more easily understood.

In the center of Fig. 33 are three vertical rows of block-like members with ten blocks in each row, placed wide apart to permit the showing of the wiring. These blocks represent diagrammatically the thirty co-acting tongue-contacts 180, 181 of the double relay

shown in Fig. 22, it being understood that the central row of said contacts is doubly tipped with silver so that the blocks may contact properly on both sides. The left-hand row of ten contacts in Fig. 33 is brought into electrical connection with the opposing co-acting surfaces of the central row of contacts when key number 13 of the manual is pressed, and the partial rocker representing the first partial is in operative position. Similarly, the right-hand row of ten contacts is brought into electrical connection with the opposing co-acting surfaces of the central row of contacts when key number 14 of the manual is pressed, and the rocker for the first partial positioned as before. Since a seventh partial is omitted in this instrument as shown, a graded "sub-octave" taking its place, and because it is more orderly to start the moving relay-contacts with the "sub", it will be noted that the first partial is crowded up to the second moving contact in each row. It will be seen, therefore, that each speaking magnet 75, (which in shop practice is always designated by the number of the key of the manual normally causing it to speak when pressed), is wired, as shown, from its nearer pole to the second contact of the associated side of the double relay bearing said manual note-number, for a double relay bears a double number in accordance with the control of its two actuating magnets by two separate adjacent keys of the manual, as heretofore explained.

In order to make the showing of Fig. 33 more easily comprehended, I have noted opposite the outside contacts of the double relay, directions for the wiring of each contact. It will thus be seen that every such contact save only the second in each outside row, invariably sends a wire to an outside second contact of some other double relay, which is always treated with regard to its numbers in such wiring, as if it were two single relays of adjacent numbers. To make it clear to which relay the second of each of these contacts is wired, the note number, which is to say the relay number, is indicated on the drawings, together with the letter of the octave and the number of vibrations normally elicited by the pressure of the similarly numbered key of the manual. For example, considering the left side of the double relay in question, which as explained is designated "relay #13", the contact marked "2" is for a prime or first partial having 64.663 vibrations per second, and known musically as the note C. The next contact marked "3", therefore, will be for the second partial which being of twice the numbber of vibrations, will be the note C an octave higher having 129.326 vibrations per second and associated with the twenty-fifth note of the manual. This third contact will accordingly be wired to the second moving contact of relay #25, the outside rows of contacts of a double relay being those referred to as "moving". All of the other contacts of the outside rows are similarly wired, it being obvious that in the case of the double relay #15, #16, the numbers applying to relay #15 will be just one number higher than those applying to relay #14 in similar cases. The same procedure will apply to relays #15 and #16, so that the entire relay wiring of the instrument may be set down from a consideration of what obtains in the case of one relay, even though it were not a double one.

In the central row of contact tongues in Fig. 33, which it will be remembered represents two similarly functioning rows in the case of single relays, each of said tongues is wired to two adjacent notes upon its associated partial-mixing rocker. For example, the tongue marked "sub" in the drawings has a wire 297 leading to a resistance 204 (see also Fig. 24) of the particular partial rocker reserved for this "sub", forty-two wires 297 being provided for an eighty-four note instrument. In this Fig. 33 the pairing of the wires at 204 as in Fig. 24, occurs electrically at the central relay contact marked "sub" where the circuit branches via its two opposing moving contacts when both are actuated. When only one contact is actuated there is obviously, only the one line. As shown, the relay #13 sends its wire 297 to the "sub" partial-rocker, said wire having, upon occasion, to serve relay #14 at the same time. Moreover, the "sub" of relay #13 being note number 1 of the manual, and the "sub" of relay #14 being note number 2 of the manual, it will be evident that the resistance 204 serving wire 297 will be connected to a "sub" partial rocker tongue representing notes numbered one and two on the manual.

From the central contact marked "5" a wire 298 leads to a resistance 204, the other end of said resistance being connected to a contact tongue 192 serving upon the fifth-partial rocker, the forty-first and forty-second notes of the manual. It will be observed that there is another fifth-partial rocker 193′ and another resistance 204′ in parallel circuit with the resistance 204 serving the partial rocker just described, and these two resistances may be of any desired ohmic value. If, therefore, the first described fifth-partial rocker be actuated, the loudness of the fifth partials will be determined by the ohmage of the resistances 204, while if rocker 193′ is actuated the resistance 204′ will determine the loudness. If both these rockers be actuated together, still another loudness will result from the simultaneous use of the two resistances and the two rockers, as will readily be seen, three different loudnesses of the fifth-partial with two rockers and their associated resistances being thus obtained. It is to be understood that any number of differences of loudness may be

given to any partial, expense of construction being the only limiting factor. I have indicated in Fig. 33 three rockers and three resistances for the second partial, making possible by proper planning of resistances as many as seven different degrees of loudness, for each rocker will give one degree, making three, and four others may be obtained by proper permutations. It will be evident that the number of the possible tonal qualities of an instrument will be increased with each addition of a different loudness to any of its partials, and a single change of this nature will make several new qualities possible, as will readily be understood.

Fig. 34 illustrates diagrammatically a single type of relay and wiring, showing also two of the keys belonging to the "operative" system, and the speaking magnets 75 which respond normally to the pressure of said keys. In this instance these are the thirteenth and fourteenth keys of the manual, for which reason the magnets are designated "speaking magnets #13 and #14". From the minus pole of current-source 226 the common wire 275 connects with all of the pedal expression-control rocker-mechanisms at their continuous, metallic, conducting angles 272 as seen in Fig. 30. Fig. 34 shows the serial arrangement of the expression control resistances, and the electrical equivalency of the single and double relays, the other details being self-evident after the description of Fig. 33. The rockers 300 are shown in perspective and broken away to indicate longitudinal continuity, the uppermost rocker contacting directly and without the interposition of any resistance, with the contact tongue 273 (see also Figs. 30 and 32), serving both of the speaking magnets 75. These magnets, as shown, normally respond to operation of keys #13 and #14 of the manual, indicated at 301 and 302, and serve to energize relay-operating magnets 165, 165′ respectively, to cause each of said relay magnets to bring together electrically the ten pairs of contacts shown immediately above it. It will be seen, therefore, that when the uppermost rocker 300 is actuated by any one of the three pedals 214, 251 or 292 (Fig. 36), the magnets 75 then sounded will speak at their loudest. If, however, the second rocker 300 be operated, the current passes from source 226 to said rocker, thence by wire 305 to and through resistance 306, and thence to speaking magnets 75 or the one thereof which is active. This cuts down by the amount of the interposed resistance the amount of current traversing the coil of magnet 75, and reduces thereby the loudness of its speech, as is obvious. If, now, no one of the pedals 214, 251 or 292 is operated, the notes played will sound with their minimum possible loudness, and current will pass from source 226 by wire 275 to and through resistance 307 and all those above it in series, reaching the speaking magnet or magnets 75 reduced to its lowest energy. Intermediate stages will of course afford intermediate results.

Referring to the partial-mixing side of the instrument as seen in Fig. 34, a condenser 308 is employed across the contacts of the prime or first partial, where the undiminished current strength is most often used. Other condensers may, of course, be used, but I have found that if the prime is taken care of, no serious arcing results. It will be seen that this showing is, electrically considered, merely a restatement of Fig. 33, similarly numbered contacts in the upper rows of the two relays being wired together as in said figure. For example, the tenth or right-hand contact in each row is so connected through the agency of the wire 309.

Fig. 35 illustrates diagrammatically the action of the whole instrument stripped of all its more or less confusing minutiae, and in the light of what has already been stated will be easily understood. The two pairs of speaking magnets 75, 75′ are associated with two pairs of adjacent notes of the manual as, for instance, numbers 13, 14 and 15, 16, two pairs of relay-operating magnets 303, 304 and 303′, 304′ serving the rows of multiple contacts 310, 311 shown below them. Four manual keys 312, 313, 314 and 315 serve to complete the circuits of their associated relay-operating magnets, said magnets being parts of the double type of relay, as shown. To avoid confusing and complicating the showing, the lines from the source 226 to the operative system are omitted, and the polarity signs used to make all clear. The slidable bar 295 which diagrammatically illustrates the expression-control system, is the equivalent of that shown in Fig. 33. Two of the double-note-serving resistances 289 of the pedal expression-control system are also shown in Fig. 35, as well as the common wire 210 leading to the silver tipped continuous rocking member 193 with which the resistances 204 are associated.

In connection with the single rocking member illustrated in Fig. 35 the resistances 289 suffice for four of the consecutive notes of the instrument, as numbers 13, 14, 15, and 16. The common wire 275 (Fig. 30) leading from current-source 226 to the slidable bar 295 is also shown in Fig. 35. In the diagrammatic showing of this figure, the two extensions marked 193 are to be considered as the equivalent of the continuous rocking member 193 of Fig. 25, and as such must be considered to move as one piece. The resistances 204 (see also in Fig. 24) must likewise be conceived of as each carrying with it its associated contact tongue 192 of Fig. 24 which cannot be shown in Fig. 35. If, now, we assume that the single rocker 193 represents the first partial of the instrument reduced

in volume by the resistances 204, we are in position to describe the operation of the whole system. Let us suppose that manual-key #13 is pressed, thus feeding current from the minus pole of source 226 to the relay-operating magnet 303, whose other pole is joined to the positive pole of said current-source, thus completing the operating circuit. As soon as the relay-operating magnet 303 receives this current it instantly brings the ten relay contacts 310 into touch with their co-acting central row of contacts associated with said magnet 303, and as the first-partial rocker 193 is the only one operating, current flows from source 226 by wire 210 to said rocker, thence through resistance 204 associated with the thirteenth and fourteenth notes, thence to the second central contact of the multiple relay, thence to the co-acting contact pressed against it on its left face from which a wire leads to the lower speaking magnet 75, from the other pole of which magnet a wire leads to a resistance 289; thence by the slidable contact representing the rockers for interposing variable resistance, to the wire 275, and back to the source 226, thus completing the circuit. If the slight changes made necessary by a diagrammatic showing have been borne in mind, this explanation will be perfectly clear, the essential principles being in no way altered when other partials are introduced into the circuit.

Fig. 36 is an exterior view of the front of the instrument, 214 indicating the bass pedal, 251 the treble pedal, and 292 the middle, sforzando, or accent pedal. The left knee-swell 293 performs the same function as pedal 292, and is intended to be used when the player is operating the two outside pedals. The right knee-swell 130 which operates the tremolo as already described, is also shown in this figure as well as the front portion of the tappet-rail 115 from which tappets 118 are seen projecting, just in front of and somewhat below the key-manual, the two tappets leaning angularly to the right being in their active position or "on". A portion of the bass end of the key-manual is shown to indicate its relative position. A large latticed opening just above the pedals, a similar opening just above the music desk, and two smaller ones beyond and above the ends of the manual, serve to release the music at the front of the instrument, and are covered beneath the lattice with a fabric suited to that purpose as well as to ornamentation. The ends and the rear of the instrument are similarly ventilated for the same purpose, and the cover is commonly lifted to the same end.

It is to be understood that the phrase "simple tones" as used throughout this specification, designates tones resulting from sensibly simple harmonic motion, or from simple or pendular vibration of the air.

What is claimed is:—

1. The method of producing compound musical tones, which consists in producing simple tones of all the requisite pitches through the employment of members of magnetic material shaped to create rhythmic variations in the magnetic fields created between said members and associated magnetizable cores adjacent thereto, whenever such cores are magnetized; transmitting the movement of said cores to members adapted to impress this movement sonorously upon the surrounding atmosphere; selecting any desired number of said simple tones of suitable pitches; and causing said tones to sound simultaneously and with degrees of relative loudness necessary to produce the predetermined effect desired.

2. The method of producing simple tones throughout the range of a musical instrument, which consists in providing twelve different pitches for each octave of said instrument, the said simple tones being produced by members of magnetic material, each said member being carried and revolved by one of six rotatively-timed shafts and being shaped to create repetitious, rhythmic variations in the magnetic field created between itself and an opposed, adjacent, associated magnetizable core, thus causing rhythmic motions of the same whenever magnetized; and transmitting the movements of said cores to members adapted to impress such movements sonorously upon the surrounding atmosphere.

3. The method of producing simple tones throughout the range of a musical instrument, which consists in providing twelve different pitches for each octave of the instrument, the said simple tones being produced by members of magnetic material, said members being carried and revolved by rotatively-timed shafts and each being shaped to create repetitious, rhythmic variations in the magnetic field created between itself and an opposed, adjacent, associated magnetizable core, thus causing rhythmic motions of the same whenever magnetized; and transmitting the movements of each core to one of a plurality of sounding-boards adapted to impress these movements sonorously upon the surrounding atmosphere.

4. The method of producing simple tones throughout the range of a musical instrument, which consists in providing twelve different pitches for each octave of said instrument, the said simple tones being produced by members of magnetic material, each said member being carried and revolved by one of six rotatively-timed shafts and being shaped to create repetitious, rhythmic variations in the magnetic field created between such member and an opposed adjacent, associated, magnetizable core, thus causing rhythmic motions of the same whenever magnetized; regulating the degree of said motions to secure proper mu-

sical expression; and transmitting the motions of said cores to members adapted to impress these movements efficiently upon the surrounding atmosphere.

5. The method of producing a multiplicity of different tone-qualities in a musical instrument, which consists in providing for the creation at will of simple tones throughout the instrument's range through the employment of members of magnetic material, each thereof being carried and revolved by one of a plurality of rotatively-timed shafts and being shaped to cause rhythmic variations in the magnetic field created between itself and an opposed, adjacent, associated, magnetizable core, whenever such core is magnetized; transmitting the movements of the cores to members adapted to impress such movements as sensibly simple tones upon the surrounding atmosphere; selecting, both for use as fundamentals and as upper partials, any desired number of said tones each thereof corresponding in pitch to some note of the gamut of the instrument; and causing the selected simple tones to sound simultaneously and with degrees of relative loudness necessary to produce the predetermined quality of tone desired.

6. The method of producing a multiplicity of different tone qualities in a musical instrument, which consists in providing for the creation at will of simple tones throughout the range of the instrument through the employment of members of magnetic material, each thereof being carried and revolved by one of a plurality of rotatively-timed shafts and being shaped to cause rhythmic variations in the magnetic field created between such member and an opposed, adjacent, magnetizable core, whenever such core is magnetized; transmitting the movements of the cores to members adapted to impress these movements as sensibly simple tones upon the surrounding atmosphere; selecting, both for use as fundamentals and as upper partials, any desired number of such tones, each thereof corresponding in pitch to some note of the gamut of the instrument; causing the selected simple tones to sound simultaneously and with degrees of relative loudness necessary to produce the predetermined quality of tone desired; and further varying at will, for proper musical expression, the loudness of all qualities produced without altering thereby their characteristic timbres.

7. The method of producing and grading compound musical tones, which consists in producing simple tones of all the requisite pitches through revolving members of magnetic material shaped to create rhythmic variations in the magnetic field created between themselves and associated magnetizable cores adjacent said members, whenever such cores are magnetized; transmitting the movement of said cores to members better adapted to impress such movement sonorously upon the surrounding atmosphere; selecting any desired number of said simple tones; causing them to sound simultaneously with the degrees of relative loudness necessary to produce the predetermined compound tones desired; and further varying, at will, for proper musical expression, the loudness of all compound tones produced without altering thereby their characteristic qualities of tone.

8. In a musical instrument, a plurality of correctly timed, revolving shafts carrying rotors, one for each note of the gamut of the instrument, said rotors shaped to cause rhythmic variations in the magnetic fields created between the rotors and associated magnetizable cores adjacent such rotors; means for magnetizing said cores; sonorous members in proximity to said cores for translating the rhythmic variations in their fields into simple tones to be combined in the surrounding atmosphere into composite tones; and means, operable at will, for selecting, grading as to relative strength, and simultaneously sounding, any one of such simple tones for a fundamental of a compound tone and any other of such simple tones for the upper partials of said compound tone.

9. In a musical instrument, a plurality of revolving shafts each carrying a plurality of rotors formed to produce for each revolution, a whole number of rhythmical variations in the magnetic field created between each of said rotors and associated magnetizable cores adjacent such rotors; a driving pulley for each shaft; a source of power; and belt-means for turning all of said shafts at speeds bearing the correct, predetermined ratios each to the others.

10. In a musical instrument, a plurality of revolving shafts each carrying a plurality of rotors, each of said rotors adapted to produce a whole number of rhythmical variations in the magnetic field created between each of said rotors and associated magnetizable cores adjacent such rotors, said variations being translatable into sound-waves; a driving pulley for each shaft; a source of power; belt-means for turning all of said shafts at speeds bearing the correct, predetermined ratios each to the others; and means for maintaining sensibly constant the absolute speed of each shaft.

11. In a musical instrument, tremolo mechanism, and means for grading at the will of the player, the loudness of the tremolo effect produced, without altering the relative loudness of the composite tones.

12. In a musical instrument of the type herein set forth, a plurality of shafts, each shaft carrying a plurality of members of magnetic material adapted to coact with associated magnet cores when said cores are magnetized; means for revolving said shafts; a plurality of sound-boards, each of said

boards serving a plurality of said cores and being set in vibration through the agency thereof; coils, serving to magnetize said cores; a source of electricity; and key-means for supplying electricity to any of said coils at will.

13. The herein described method of producing a compound musical tone, which consists in creating through the agency of revolving magnetic members and opposed co-acting magnetized members, a plurality of sets of undulations in a similar number of magnetic fields, each set being characterized by the periodicity and the relative strength of one of the partials of the tone desired; and simultaneously translating each set of undulations into a sensibly simple sonorous wave in the air, the plurality of simple sounds so produced being impressed upon the ear as a single compound tone of the predetermined pitch and quality.

14. In a musical instrument, the combination of means for generating tones from the interaction of revolving members of magnetic material and associated, magnetized members adapted to vibrate sonorous means; and means for electrically joining together in pairs, certain parts associated with notes of the instrument's gamut bearing to each other the relation of musical seconds.

15. In a musical instrument, the combination of means for generating tones through the agency of revolving members of magnetic material having peripheries exhibiting repetitious, equally spaced protuberances; and magnetizable members each thereof provided with a plurality of similarly-spaced protuberances adapted to co-act with those of the first-named members in the production of tones.

16. In a musical instrument, the combination with a magnetizable member, of an opposed, revolving, co-acting member of magnetic material having a periphery exhibiting repetitious, equally-spaced protuberances and spaces therebetween, the transversely-axial length of said spaces being materially greater than that of said protuberances.

17. In a musical instrument, the combination of means for generating tones through the agency of revolving members of magnetic material having peripheries exhibiting repetitious, equally-spaced teeth or protuberances; and magnetized members co-acting therewith and transmitting their motion to amplifiers associated with sonorous means and serving both to enlarge the motion thereof and to round the form of the air-wave given off thereby.

18. In an electrical musical instrument of the type herein set forth, the combination of a plurality of sound-boards, each thereof associated with a plurality of rotating shafts; a plurality of members of magnetic material revolved by each shaft; and co-acting magnetizable members each associated with one of the revolving members and transmitting its motion to one of the sound-boards.

19. In a musical instrument playable from a key-manual, the combination of tone-generating mechanism; a single expression-control means adapted to grade at will the loudness of the tones educed throughout the range of the instrument; and means, also operable at will, to separately control as to loudness, the upper and lower sections of the instrument's compass.

20. In a musical instrument of the type herein set forth, a plurality of shafts, each shaft carrying a plurality of members of magnetic material adapted to co-act with associated magnet cores when said cores are magnetized; means for revolving said shafts; a plurality of sound-boards; a magnet-rail; magnets mounted in said rail in proximity to said sound-boards and having cores projecting through said boards; coils serving to magnetize said cores, the sound-boards being set in vibration through the agency of said cores; amplifiers associated with said magnets; a source of electricity; and key-means for supplying electricity to any of said coils at will.

21. In a musical instrument of the type herein set forth, a plurality of shafts each carrying a plurality of members of magnetic material adapted to co-act with associated magnet cores when said cores are magnetized; means for revolving said shafts; a plurality of sound-boards each serving a plurality of said cores and vibratable thereby; coils, serving to magnetize said cores; keys for supplying electricity to any of said coils at will; a block beneath each key, carrying a plurality of contacts; a flexible tongue adapted to bridge the contacts of said block; a source of current; and wires connecting each of said contacts with said source of current.

22. In an electrical musical instrument of the type herein set forth, the combination of a plurality of sound-boards, each thereof associated with a plurality of rotating shafts; a plurality of members of magnetic material revolved by each shaft; co-acting magnetizable members each associated with one of the revolving members and transmitting its motion to one of the sound-boards; keys for supplying electricity to any of said magnetizable members at will; a block beneath each key carrying a plurality of contacts; a flexible tongue adapted to bridge the contacts of each block; relay magnets in circuit with each of said contacts; and means for opening and closing at will, the circuits between said relay magnets and said contacts.

23. In a musical instrument playable from a key-manual, the combination of mechanism for generating simple tones throughout the range of said instrument; means for selecting any desired number of said simple tones and

simultaneously sounding the same as a composite tone of the pitch and quality desired; means for controlling at will, the loudness of the tones educed throughout the range of the instrument; and means, also operable at will, to separately control as to loudness, the upper and lower sections of the gamut of the instrument.

In testimony whereof I have signed my name to this specification.

MELVIN L. SEVERY.