

June 27, 1933.

B. F. MIESSNER ET AL

1,915,859

METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Filed Aug. 20, 1931

3 Sheets-Sheet 1

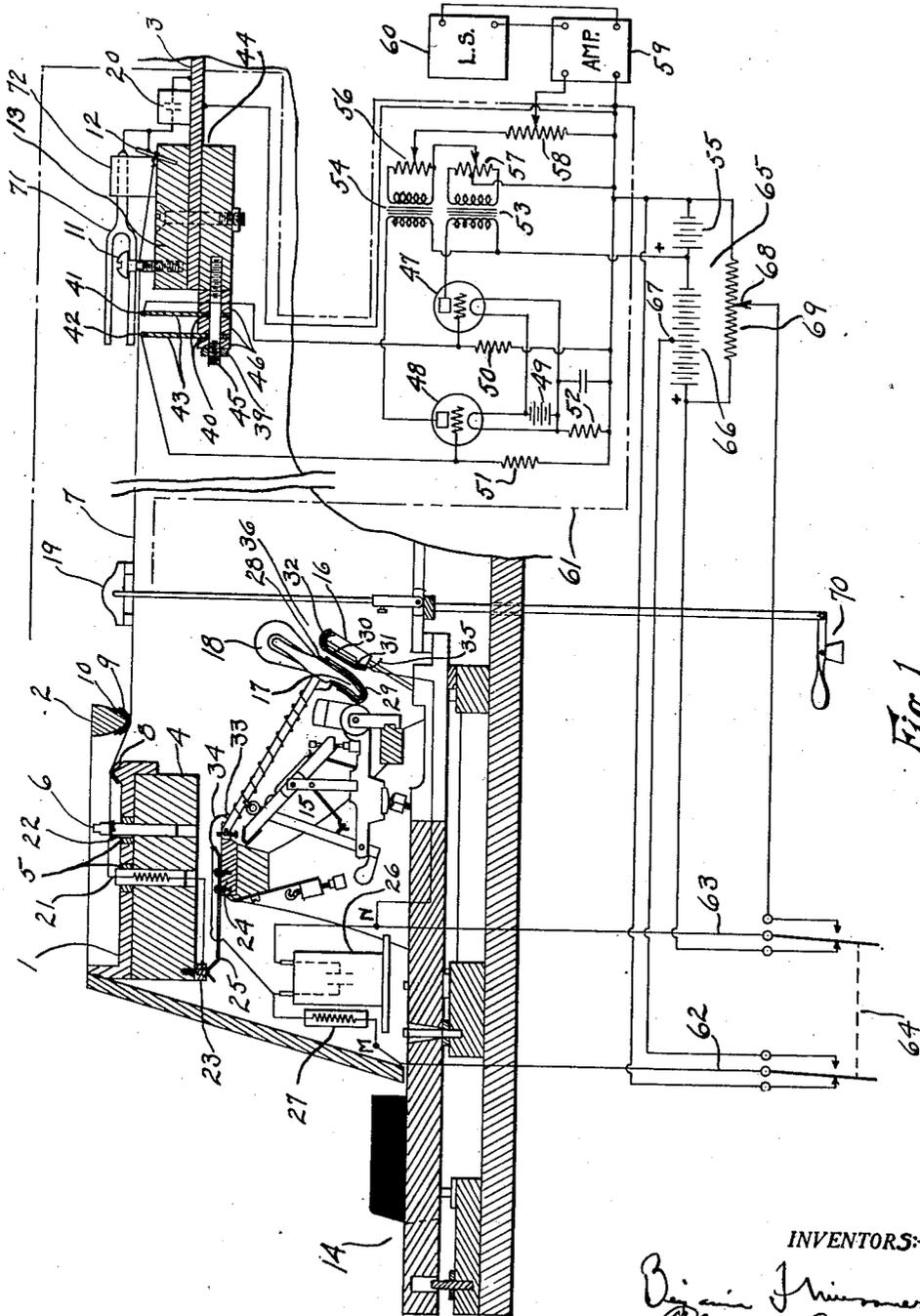


Fig. 1

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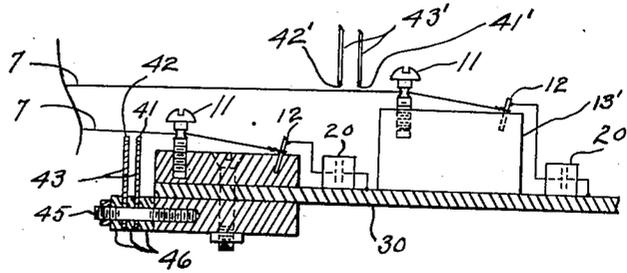


Fig. 2

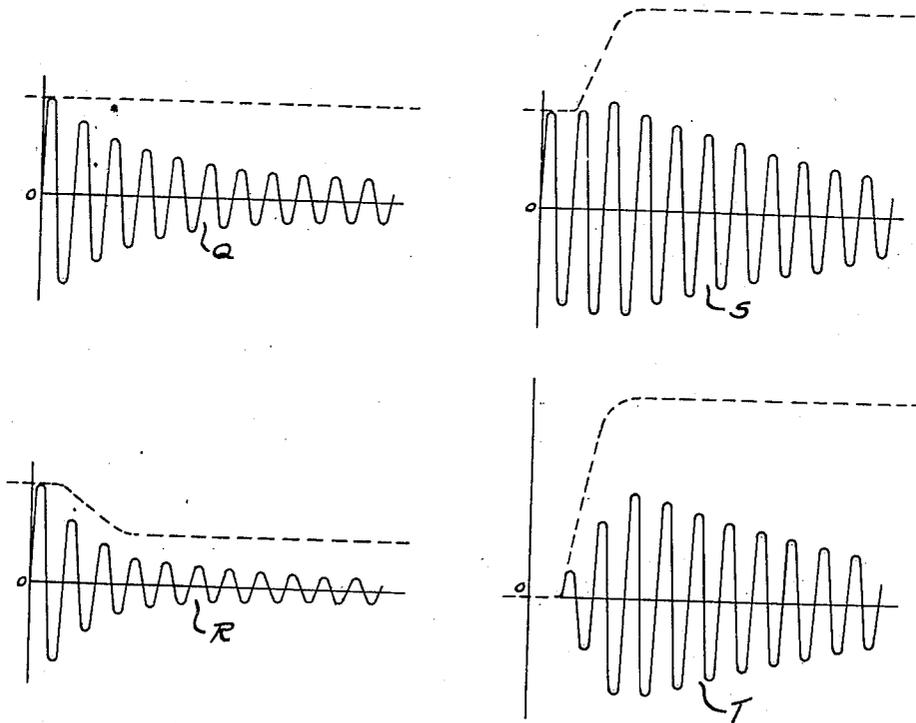


Fig. 6

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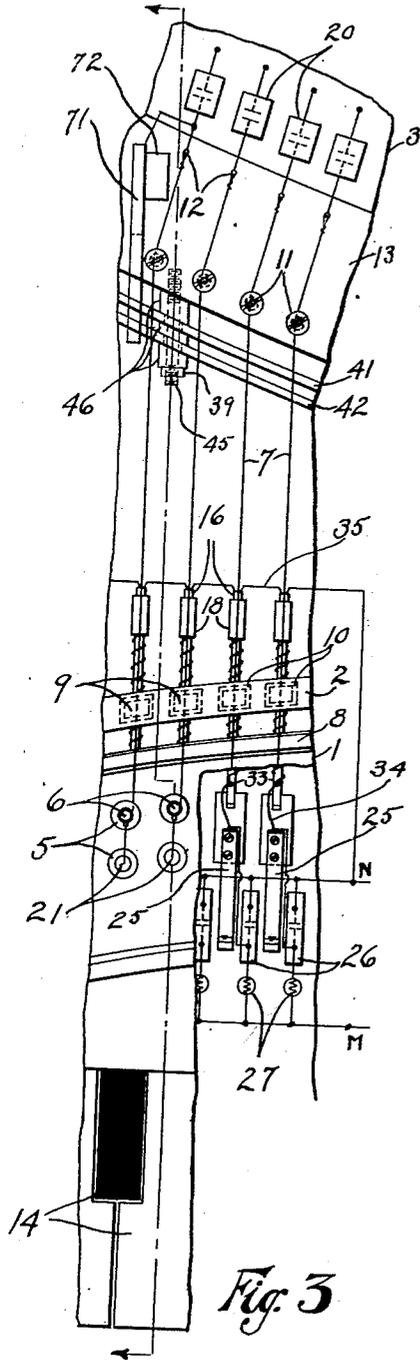


Fig. 3

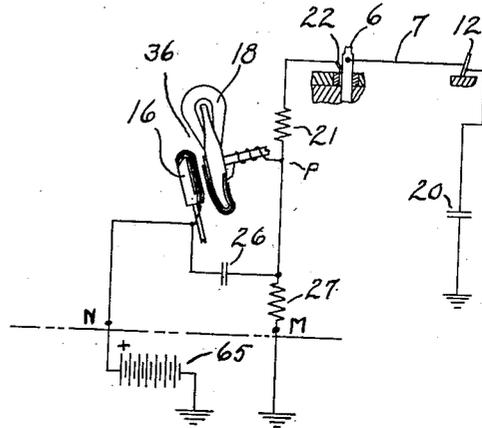


Fig. 4

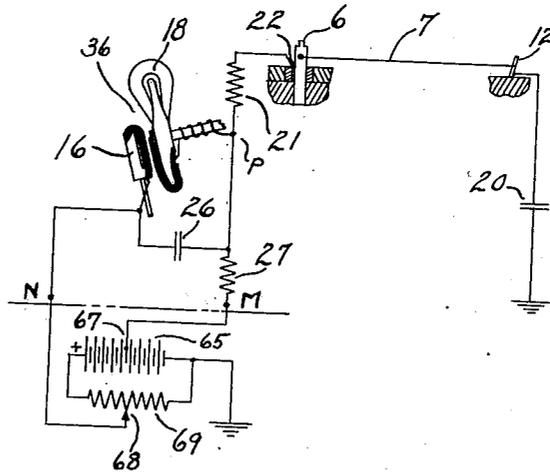


Fig. 5

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## UNITED STATES PATENT OFFICE

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## METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Application filed August 20, 1931. Serial No. 558,207.

This invention relates to musical instruments and systems wherein the vibrations of tuned bodies are translated into electric oscillations i. e., wherein mechanico-electric translation is employed and such oscillations employed for the actuation of further apparatus; and more particularly to improvements in, and an improved form of, such a musical instrument. Although any form of tuned body and any mode of excitation thereof may be employed in an embodiment of the invention, we prefer to employ strings as vibrators and have illustrated an instrument containing strings caused to vibrate by percussion.

This application is in part a continuation of our co-pending application, Serial Number 538,733, filed May 20, 1931. Instruments of the class described and improvements therein have also been disclosed generally in the co-pending application of Benjamin F. Miessner, Serial Number 512,399, filed January 30, 1931; and certain improvements more specifically relating to the translating devices therein have been disclosed in the co-pending application of Benjamin F. Miessner, Serial Number 528,750, filed April 9, 1931.

In our co-pending application above referred to, Serial Number 538,733, we disclosed methods and apparatus for varying the initial or early amplitude-time characteristics of tones produced, as by percussion, in an instrument of the class described, so as to simulate an organ or other non-percussion instrument. This application deals with such methods and apparatus, with improvements thereon and extensions thereof, with methods and apparatus for further and otherwise varying the initial or early amplitude-time characteristics of the tones to produce still other effects, and with a generally improved instrument of the class described. Thus one of the forms of the present invention comprises an instrument wherein the vibrators are excited by percussion, the instrument being provided with simple controls by the use of which the output tones may optionally be stripped of their percussion produced impact component and momentarily high initial amplitude, being thereby ren-

dered organ-like; or may be made to retain the impact component and high initial amplitude, closely followed by a decrease in amplitude, such decrease being of degree controllable from a negligible to a substantial value.

This decrease we have found of great value in the simulation of other instruments producing tones having an appreciable rate of damping. In order that a non-continuously excited vibrator be useful in an instrument which is at times employed for the simulation of an organ or other tone-sustaining instrument, it is necessary that it be so mounted and otherwise so employed as to have inherently a very low rate of damping. If then with such vibrators it is desired at other times to simulate a piano, for example, the rate of damping of the vibrators will frequently be found too low, since an outstanding and important characteristic of the tone of the piano is a very perceptible decrease in amplitude closely following tone commencement. We have found that such effect is quite satisfactorily simulated by a decrease in amplitude beginning just after tone commencement and continuing for a small fraction only of the total time during which the vibrator may vibrate. The overall amplitude-time characteristics of tones, in the amplitude of which such decrease has been effected, may even be musically preferable to those of the instrument being simulated, in that the important early decrease in amplitude is effected without the usual accompaniment of early termination of the tone.

Thus it is an object of our present invention to provide, in a musical instrument of the class described, improved methods for reducing or eliminating impact components and/or high initial amplitudes from the output tones; and it is a further and allied object to provide improved methods and apparatus for delaying after key depression the commencement of the output tones produced by a key operated instrument of the class described.

A further object is the provision of methods and apparatus for producing a change of predeterminable degree in the amplitude of

the output tones produced by such an instrument, such change closely following the commencement of the tone; and a further and allied object is the provision of methods and apparatus for regulating the degree and direction of such change and for eliminating the same at will and for optionally eliminating impact components and high initial amplitudes of such output tones.

It is a further object to provide an improved electrical musical instrument, by the output tones of which may be simulated, in respect of amplitude-time characteristics, the tones of another instrument or selectively the tones of a plurality of other instruments; and it is another object to provide generally an improved musical instrument of the class described.

Restricted objects include the provision of suitable means and method for voicing the instrument, of improved translating device, of convenient action connection, of improved vibrator insulation and of convenient tuning standards. Other and allied objects will more fully appear from the following description and the appended claims.

We have found it convenient to employ the string frame, repeating action, dampers, pedals, case and certain other components of the well known grand piano in an embodiment of our invention; and accordingly the accompanying drawings, to which reference is hereinafter had, may be described as follows:—

Figure 1 is a vertical cross-sectional view of a portion of the instrument, taken parallel to one of the treble strings and along line 1—1 of Figure 3, showing partly diagrammatically and partly schematically the electrical elements and circuits associated with the action and strings;

Figure 2 is similarly a vertical cross-sectional view of a smaller portion illustrating for the bass or customarily overstrung strings an adaptation of our invention;

Figure 3 is a plan view of a small portion of the instrument with the dampers omitted for the sake of clarity;

Figure 4 is a schematic electrical diagram for the separate illustration of the circuit associated with each string when switch 64 is in the left-hand position, as shown in Figure 1;

Figure 5 is a similar electrical diagram for the separate illustration of the circuit associated with each string when switch 64 is in the right-hand position; and

Figure 6 is a group of four oscillation curves illustrating the action of our invention in certain of its adjustments.

Reference being had to the first figure, 1, 2 and 3 may comprise portions of an integrally cast frame, as a piano frame, 1 being hereafter referred to as the "front frame", 2 as the "capo", and 3 as the "rear frame". Underneath the front frame may be provided

wrest-plank or pin-block 4, of non-conductive and mechanically suitable material. Passing through insulating bushings 5 in front frame 1 and into wrest-plank 4 may be tuning pins 6. From the tuning pins may be strung strings 7, over insulating strip 8 and under capo 2. Each string 7 may be provided with a metal bearing at capo 2 in the form of a separate, thin, curved, metal piece 9, the latter insulated from capo 2 by thin mica or other insulation 10. At the rear string 7 may bear against the side of adjusting screw 11, preferably resting in a continuous groove cut in the screw, and be secured as by an eye in the string to hitch-pin 12. Both adjusting screws 11 and hitch pins 12 may be insulated from rear frame 3 by bakelite or other insulating block 13, into which 11 may be screwed and 12 driven. The several strings, of which only one per musical note need be employed and which must each be a separate wire, but which may comprise a group of strings otherwise similar to that of the conventional piano, will thus be seen to be individually electrically insulated from each other and from the metal frame of the instrument. Keys 14, action 15 and dampers 19 may be employed as in the conventional piano; but certain changes in the back-checks 16 and certain additions to the hammer-tails 17 and hammers 18 may be made, and certain electrical apparatus and circuits included in association with the strings and action.

Thus between each string 7 and the frame may be electrically connected a separate condenser 20, as shown between hitch pins 12 and rear frame 3. Each string 7 may further connect to a separate resistor 21, as through the medium of its tuning pin 6 and a thin metal strip 22 held in contact with the tuning pin by bushing 5 and wrest plank 4. Each resistor 21 may conveniently be mounted in a hole in wrest plank 4, through an insulating bushing 5 in front frame 1. The lower end of the resistor connected to each string may be wired to an individual contact or contact screw 23 mounted in the bottom of wrest plank 4, each contact 23 being positioned in approximate alignment with the flange 24 of the hammer 18 arranged to strike such string. In order to preserve the ready removability of the keys 14 and action 15, electrical connection from each contact 23 to further apparatus associated with the action may conveniently be made by means of a contact spring 25 screwed to each hammer flange 24. Suitably mounted to the key bed and fixed parts of the action may be provided a condenser 26 for each key, one terminal of each such condenser being connected to the associated contact spring 25. The other terminals of the condensers 26 may be connected together to form a common electrical connection N, hereinafter re-

ferred to as such. To a second common electrical connection M, but through individual resistances 27, may be connected each contact spring 25 (or the lug of a condenser 26 connected thereto).

Across each condenser 26 is provided a "switch" 36, arranged to be closed just after an impact of the associated hammer with the associated string produced by depression of the associated key, and arranged to be opened upon release of such key. Although more than one arrangement in and about the action may be employed to act as such a switch, we have found it desirable to employ the hammer-tail 17 and the associated back-check 16 as the two mechanical elements of the switch 36, equipping each of them at and near its region of contact to the other with a metal strip. Such metal may be covered by a thin piece of chamois or other leather, impregnated with a colloid graphite solution such as is sold under the trade name of "Aquadag"; or with some other relatively soft but conductive material. Thus to each hammer-tail 17 may be glued or otherwise fastened metal strip 28; and impregnated leather strip 29 may be glued or otherwise fastened, preferably at or near its extremities only, to metal strip 29. In similar manner over the customary felt 30 of each back-check 16 may be fastened metal strip 31; and impregnated leather strip 32 may be glued or otherwise fastened, preferably at or near its extremities only, to metal strip 31. Each strip 28 may be wired, as by a fine wire, to a lug 33 on the hammer stem near its pivot, and the lug 33 in turn connected as by flexible connection 34 to the associated contact spring 25. All strips 31 may be connected together, as by loose flexible connection 35, and to common electrical connection N.

For the translation into electric oscillations of the vibrations of the strings 7 there are provided thin, narrow conductive strips 41 and 42 positioned underneath the several strings 7; each is preferably so curved as to lie under each string at a point which similarly divides its active vibratory length from capo 2 to adjusting screw 11—e. g., so that strip 41 lies under each string at a point say  $\frac{1}{18}$ th of its active vibratory length forward of adjusting screw 11 and so that strip 42 lies under each string at a point say  $\frac{1}{6}$ th of its active vibratory length forward of adjusting screw 11. These strips require to be very well insulated from the frame; and to this end we prefer to cement each to the top edge of long, somewhat flexible bakelite or other insulating strip 43 and to mount such strips at frequent points in their length to the frame, or to a block 44 affixed to the frame, by means of threaded rods 45, nuts 39, and spacers 46, positioning screws and spacers 46 near the bottom edge of strips 43 so as to

present the greatest convenient length of leakage path from strips 41 and 42 across the surface of strips 43. Oversize holes 40 bakelite in strips 43 may be employed to facilitate vertical adjustment of the strips 43 and hence of the position of the metal strips 41 and 42 with respect to the strings.

The bass strings of the usual piano are overstrung—e. g., while their forward ends in general form a series with those of the other strings, their principal length may be disposed above the other strings, angularly with respect thereto. With such arrangement we have found it convenient to employ, as shown in the partial, cross-section Figure 2, auxiliary metal strips 41' and 42', electrically connected to strips 41 and 42 respectively, and cemented to the bottom edge of bakelite strips 43', which may in turn be mounted to the frame in any convenient manner—such mounting preferably contacting with strips 43' near the top thereof for the minimization of leakage to or from 41' and 42', as above discussed for strips 43. In Figure 2 also is shown an auxiliary insulating block 13' for holding the adjustment screws 11 and hitchpins 12 for the bass or overstrung strings.

Each of the strips 41 and 42 may be connected to the grid of a thermionic vacuum tube, such tubes being shown as 47 and 48 respectively in Figure 1. The cathodes of these tubes may be energized by battery or other current source 49; and their grids may be biased negatively with respect to their cathodes, through resistors 50 and 51 respectively, by the flow of their anode current through condensively by-passed resistor 52, as will be understood. In the output circuits of these tubes may be provided transformers 53 and 54, respectively; and a common battery or other anode current source 55 may be employed for the two tubes. Across the secondary of transformer 54 may be provided potentiometer 56 and across the secondary of transformer 53 center-tapped potentiometer 57. A variable portion of each of these two potentiometers may form a series circuit with the entire resistance of potentiometer 58 as shown; and between the variable contact and one end of the resistance of potentiometer 58 may be connected the input of an electrical amplifier 59, to the output of which may be connected loudspeaker or other electro-acoustic translating device 60. Electrostatic shielding 61 may advantageously be provided about the tubes 47 and 48 and their associated apparatus, about the leads to their grids, and at least partially about the strings 7 and strips 41 and 42, etc. Such shielding, the lower ends of resistors 50 and 51 (grid returns for tubes 47 and 48), and the frame of the instrument (e. g. rear frame 3) may be electrically connected together.

The common electrical connections M and N abovementioned may be wired to the two

poles 62 and 63 respectively of double-pole, double throw switch 64. With this switch is the left-hand position, as it is shown, M is connected to the negative of battery or source 55, or in other words to the frame 1—2—3. At the same time N is connected to the positive of battery or other potential source 65, which may if desired include battery or source 55 and further source 66 in series. With the switch in the right-hand position, M may be connected to an intermediate potential in battery or source 65, such as is represented by tap 67, and N may be connected to the movable contact 68 of a potentiometer or other voltage varying device 69 shunting the battery or source 65. It will be understood, of course, that a suitable rectifying, filtering and voltage adjusting system operating from an alternating current source may replace the battery or source 65, if desired, as a source of the various potentials derived therefrom; likewise that tubes 47 and 48 may be unipotential cathode tubes having heater elements energized from alternating current instead of battery 49, or tubes as shown but with cathodes energized from rectified alternating current, etc.

In Figure 3 a portion of the mechanical apparatus shown in Figure 1, with dampers 19 removed, appears in plan view; a section of wrest plank 4 has been broken away for the clearer depiction of the parts underneath the same.

The functioning of the apparatus shown may be most clearly described by first assuming a potential difference to exist between a string or strings and frame 1—2—3; and thereafter by showing in what manner and at what times such potential difference is caused to exist. When such potential difference exists between a string 7 and the frame, the minute electrical capacity between the string and each of the metal strips 41 and 42 is charged to that potential, due to the connection of strip 41 to the frame through resistor 50 and of strip 42 through resistor 51. Vibration of string 7 in a vertical plane varies this capacity, and causes the instantaneous voltage across it to vary, in accordance with the frequency of vibration of the string 7 and with the waveform of the vibration of the mean point of the string opposite the strip. These voltage variations are, of course, oscillatory in character, and in reality comprise an a. c. voltage, the amplitude of which depends on the value of d. c. potential difference applied between string and frame, and on the amplitude of vibration of the string. The a. c. voltage thus developed by any string and strip 41 is seen to be applied to the grid of tube 47, and that developed by any string 7 and strip 42 to be applied to the grid of tube 48. These voltages are respectively amplified by those tubes and transformers 53 and 54 and caused to appear

respectively across potentiometers 57 and 56. From these potentiometers such voltages, each regulable in amplitude and that across center-tapped potentiometer 57 regulable in phase with respect to that across potentiometer 56, are applied to potentiometer 58; and from this potentiometer a composite voltage of regulable amplitude may be applied to the input of electrical amplifier 59, the output of which is translated into sound by loud-speaker 60.

One of the strips 41 and 42, one of the tubes 47 and 48, one of the transformers 53 and 54, and both the potentiometers 56 and 57 may be omitted, if desired, the function of the plurality of translating systems as shown being to permit variation of tone quality, or harmonic structure, as is disclosed in U. S. Patent 1,906,607, issued May 2, 1933, to Charles T. Jacobs. Such harmonic structure control arises from the difference in harmonic composition, or waveform, of the vibration of the mean string point opposite the two strips 41 and 42, the consequent difference in harmonic composition of the a. c. voltages applied to the grids of tubes 47 and 48, and the infinite variety of amplitude relationships and the dual phase relationships in which these voltages may be combined or algebraically added, after amplification, by various adjustments of the potentiometers 56 and 57. The number of such translating systems need not of course be limited to two, such number being only illustrative herein.

From the foregoing it may be considered that the value of d. c. potential difference applied between string or strings and frame determines the efficiency of translation of the vibrations of such string or strings into electric oscillations, such efficiency being zero when no such potential difference exists, being at a maximum for a particular case when the maximum potential difference therein available exists, and rising and falling as such potential difference may be caused to rise and fall.

Attention now being directed to the manner in which, and the times at which, potential difference is caused to exist between a string or the strings 7 and the frame, it will be seen that with switch 64 in the left-hand position, as shown, each string 7 is normally at the same potential as the frame, due to its connection to the point M through its associated resistors 21 and 27, and to the connection of the point M through the switch 64 to the frame. The efficiency of translation is therefore zero and, were the string to be in a state of vibration, no a. c. voltage would be produced thereby at the grid of either tube 47 or tube 48. If now one of the keys 14 be depressed, its damper 19 will be lifted from the associated string 7; and its hammer 18 will be propelled toward and caused to strike the string, setting the latter

into vibration. The hammer 18 will immediately rebound from the string and, unless the blow be an extreme, incomplete "staccato", the leather surface 29 on the hammer-tail 17 will be driven into contact with and will frictionally engage the leather surface 32 of the back-check, now occupying a raised position, as will be understood by those skilled in the piano art. Otherwise expressed, the switch 36, comprising the metal strips 28 and 31 and the conductive leather strips 29 and 32, will be closed just after impact of the hammer 18 and string 7.

Reference may conveniently be had to Figure 4, wherein a switch 36 and other circuit components associated with each of the several strings 7 appear above the dotted horizontal line, illustrated for a single string; while the battery connections common to all the several string circuits when switch 64 is in the left-hand position appear below such line. It will be seen that upon closing of switch 36 the associated condenser 26 begins to discharge through the residual resistance of the switch and current begins to flow through the switch and resistance 27 from the positive to the negative of battery or source 65. This causes the potential of the point P in Figure 4 to rise and the condenser 20 to charge from point P through resistance 21, thus in turn raising the potential of the string 7. The rise of potential of the string will be gradual, rather than instantaneous, since it requires time for the condenser 26 to discharge through the residual resistance of switch 36 and for condenser 20 to charge through resistance 21. Thus the efficiency of translation into electric oscillations of the vibration of string 7 will rise gradually, rather than abruptly, at a rate determined by the electrical values of the circuit components. The vibration of the strings, produced by the impact of hammer 7 immediately preceding the closing of switch 36, therefore begins to produce an a. c. voltage at the grid of each of the tubes 47 and 48, and hence a tone in loudspeaker 60, just after the impact; and these voltages and tone rise in amplitude according to the rate of rise of potential between the string and frame. The limit to which the potential difference, and hence the translation efficiency and loudspeaker output, may rise is of course determined by the voltage of battery or source 65, and by the relative values of resistance 27 and residual resistance of switch 36.

Thus with the setting of switch 64 in the left-hand position the tone starting characteristics of the organ and similar instruments are simulated. No impact component in the tone is produced, since impact of hammer and string occurs while translation efficiency for that string is still zero; and the amplitude of the tone rises gradually, rather than abruptly, simulating the gradual rise of tone from a

wind-operated pipe. In order that the tone continuation characteristics may as closely as possible simulate those of the organ or other tone-sustaining instrument, it is important that the string bearings at front and back of the active vibratory length of the string—i. e., metal pieces 9 and adjusting screws 11—be extremely rigidly mounted, in order that a minimum absorption of the energy of the string by its supports take place, thus reducing to a minimum the inherent rate of damping of the strings 7. Tone termination characteristics are established principally by the drop to zero of potential between the string and frame—i. e., of translating efficiency—due to opening of switch 36, which will be understood by those skilled in the art to occur at the beginning of the release of key 14; but suitably rapid termination is aided by the return to contact with the string of damper 19, which occurs just before the completion of key release. If rapid repetition of the playing of a note be indulged in, it may happen that the impact of hammer with string on a subsequent depression of the key 14 will occur before the drop to zero of translating efficiency attending the immediately preceding key release has been completed. In such cases a slight impact component may be produced in the tone or tones produced by such subsequent depression or depressions of the key; this we have not found objectionable, it serving at times as an advantage, in that it tends to improve the delimitation of the several repeated notes over that produced by the usual organ.

The potential difference between strings and frame when the poles of switch 64 are thrown to the right-hand position may now be considered. From either Figure 1 or Figure 5, a view similar to Figure 4 but for switch 64 in the right-hand position, it may be seen that normally (switches 36 being open) each string is established at the potential of tap 67 on battery or source 65. The somewhat lower voltage at this tap than at the positive terminal of battery or source 65 may advantageously be employed for the equalization of the apparent volume output from the loudspeaker between conditions of right and left-hand positions of switch 64, since with this switch in the left-hand position the string never receives the full potential of battery or source 65, due to voltage drop in the residual resistance of switch 36. If at the same time the movable contact 68 of potentiometer 69 be adjusted to the potential of tap 67, no change in circuit conditions will be caused by the closing of any switch 36. Consequently a steady, finite, translating efficiency is maintained at all times for all strings, regardless of the position of any key or keys 14, all strings 7 being rendered at a steady potential difference from the frame. If now any key 14 be depressed, its damper

19 lifted from the associated string 7 and its hammer 18 propelled toward and caused to strike the string, the immediately subsequent closing of the associated switch 36 is of no significance; and there will be produced in the loudspeaker a tone having an impact component, a high relative initial amplitude, and generally an abrupt inception, analogous to that of the usual piano tone. After subsidence of the high initial amplitude, tone continuation characteristics are similar to those obtaining when switch 64 is in the left-hand position, the complete amplitude-time characteristics creating a tone generally similar to that of the usual piano but of somewhat lower damping rate. Tone termination characteristics are not contributed to or influenced by any electrical action, but are established merely by contact of damper 19 with string 7 upon release of key 14.

With switch 64 still in the right-hand position, but with the movable contact 68 of potentiometer 69 adjusted to some potential less than that of tap 67, the action of the switches 36 again becomes of significance. In such case the basic tone inception characteristics are similar to those last above discussed; but immediately after tone inception the closing of switch 36 causes associated condenser 26 to begin to discharge through the residual resistance of switch 36 and current to begin to flow through switch 36 and associated resistance 27, lowering the potential of point P, reducing the charge in associated condenser 20, and thus reducing the potential of the string 7—gradually, rather than abruptly, as before. Thus immediately after the abrupt tone inception there occurs an augmented decrease in amplitude of the tone, of higher degree the lower the potential to which movable contact 68 has been adjusted. The length of time during which this decrease continues is comparable to the length of time required, when switch 64 is in the left-hand position, for the tone to reach full amplitude after its inception—such length of time may be and is preferably made small compared to the duration of any but short or “staccato” tones. The degree of augmentation of amplitude decrease may be made slight by adjustment of movable contact 68; or appreciable, to simulate the somewhat rapid damping of the usual piano tone; or extreme, to simulate for example such a tone as that of the xylophone. After the decrease is sensibly completed, tone continuation characteristics are similar to those obtaining when switch 64 is in the left-hand position; and tone termination characteristics are of course the same as those last above discussed.

A fourth condition is that wherein switch 64 is still in the right-hand position, but the movable contact 68 is adjusted to a higher potential than that of tap 67. In this case the abrupt tone inception again occurs; but the

immediately ensuing normal decrease in amplitude resulting from subsidence of the high initial amplitude is opposed by a tendency toward increase, to an extent determined by the adjustment of movable contact 68. With higher potential adjustments of this movable contact the net result produced may be made a definite increase closely following tone inception. Following the early characteristics, tone continuation and termination characteristics are similar to those obtaining in the other two cases wherein switch 64 is in the right-hand position.

Certain modifications of tone continuation and termination characteristics hereinabove discussed are effected by the use of a “loud” pedal, such as is customary on the usual piano for the purpose of raising the dampers (19) from the strings (7). Such a pedal is shown in Figure 1 as pedal 70. With switch 64 in the left-hand position the lifting of dampers 19 from strings 7 by pedal 70 removes the augmentation effected by the dampers 19 of the basically electrically produced tone termination occurring upon key release; but this is not a particularly decided effect. With switch 64 in the right-hand position, however, the raising of dampers 19 by pedal 70 removes entirely the tone terminating action which otherwise takes place upon release of a key 14. It is furthermore to be observed that if a tone be sustained by pedal 70 and its key 14 released, any early amplitude increase or decrease which may have been effected as abovementioned due to positioning of movable contact 68 at a higher or lower potential than that of tap 67 will be counteracted upon such release of its key 14. Pedal 70 also may be employed to promote to some extent sympathetic vibration of non-struck strings harmonically related in pitch to strings actually struck, etc., as on the usual piano.

The length of time elapsing between the inception of a tone and the attainment thereby of sensibly full volume when switch 64 is in the left-hand position, or between the inception of a tone and the attainment thereby of its reduced or increased volume when switch 64 is in the right-hand position, may be fixed at any desired value by suitable choice of the values of the several components of the circuit associated with each string—i. e., those shown above the dotted line in either Figure 4 or Figure 5. If desired, such length of time may be variously established for different notes of the instrument by differentiation of the values of one or more of the components between the circuits associated with the several strings. It will of course be understood that various modifications may be made in the internal arrangement of the several circuits without altering their fundamental action. We have preferred, however, to employ for each

string the circuit illustrated, with values of components of the order tabulated below;—

Condenser 20, .05 microfarad. Resistance 21, 1 megohm.  
Condenser 26, .1 microfarad. Resistance 27,  $\frac{1}{4}$  megohm.

We have employed leather strips 29 and 32 in the switches 36 impregnated with colloidal conductive solution of proper strength to yield switches having a residual, or closed, resistance of approximately 50,000 ohms. While a simpler form of switch contact may be employed on either hammer-tail 17 or back-check 16 or both, we have found that the conductive leather contact surfaces coincidentally provide a sufficiently rough surface to permit proper frictional engagement of hammer-tail and back-check in operation, and provide a switch which is not entirely abrupt in opening and closing. This latter characteristic is due to the compressibility of the leather and the variation in the transverse resistance of the leather and metal strip assembly with pressure thereon, such resistance being higher when the switch is open, and just as it begins to close or completes opening, than when the switch is fully closed by frictional engagement as abovementioned of its two members. Such switches may of course be made and employed in similar manner with the upright piano action, the back-stops in such action, which are in fixed relation to the several hammers and frictionally engage the several back-checks, being equipped and utilized as are the hammer-tails 17 shown in Figures 1, 4 and 5.

We include as Figure 6 of the drawings four illustrative oscillation curves, plotted against a horizontal time axis. In each case the point O denotes horizontally the instant of excitation of a vibrator and vertically a zero value; the dotted line denotes the translation efficiency with reference to the instant of excitation, and the heavy curve the instantaneous electric voltages produced by translation of the vibration ensuing such excitation. Thus curve Q may represent a case wherein switch 64 is in the right-hand position and the movable contact 68 of potentiometer 69 is adjusted to the potential of tap 67—i. e., a case wherein a steady translating efficiency is maintained at all times. Curve R may represent oscillations produced when switch 64 is again in the right-hand position but movable contact 68 adjusted to a potential lower than that of tap 67, an adjustment which provides a decrease in translation efficiency closely following vibrator excitation. Curve S may represent oscillations produced when switch 64 is again in the right-hand position but movable contact 68 adjusted to a potential higher than that of tap 67, an adjustment which provides an increase in translating efficiency closely following vibrator excitation. Finally curve

T may represent oscillations produced when switch 64 is in the left-hand position—i. e., when translation efficiency is normally zero but begins a rise to a finite value closely following vibrator excitation. It will be understood that these curves are illustrative only and are susceptible of modification in absolute and relative form, steepness, etc., as the result of choice and arrangement of circuit components.

Wide further modifications in and substitutions for the apparatus shown in the figures may of course be made without departure in manner of employment from the novel general method of varying translation efficiency about and after the instant of original excitation of the tuned body: thus, for example, key-actuated mechanical devices, or electro-thermal-mechanical systems electrically operated by the keys, may be employed to move the translating devices with respect to the vibrating bodies. It will also be appreciated that the general arrangements hereinabove disclosed are not limited in usefulness to the capacitive mechanico-electric translating devices illustrated, being available for use with other translating devices, as for example to delay the rise of magnetizing current in an electromagnetic translating device. It will finally be seen that we have disclosed, among other things, an instrument employing for excitation of its tuned bodies the simple and flexible method of percussion, together with means and methods for freeing the instrument of the limitation of producing only a "percussion type" of tone.

For evenness between different notes of apparent volume output from loudspeaker 60 with similar blows upon the several keys 14, and for similarity between different notes of tone quality with any given adjustment of the potentiometers 56 and 57, it is important that the spacings between the strips 41 and 42 and the several strings 7 be properly adjusted relative to each other. A procedure which we have found satisfactory for effecting such adjustment is as follows:—

With the height of the rear ends of the active portions of the strings 7 roughly adjusted by means of the several adjusting screws 11 so that the strings lie approximately in a plane, the strip 41 is vertically adjusted so that a hard blow on any key 14 will produce vibration of the associated string such that the string almost, but not quite, touches strip 41. This will require much closer positioning of the strip 41 to the strings 7 in the high treble than in the lower pitch portions of the instrument, due to the much lower vibration amplitudes of the strings in the high treble. Then with the amplifier and loudspeaker operating and with the movable contact of potentiometer 56 at the bottom of

its resistance so that only translation effected by strip 41 actuates the loudspeaker, the individual adjusting screws 11 are so adjusted that similar blows on the various keys 14 produce similar apparent sound volumes in loudspeaker 60. Otherwise expressed, the instrument is "voiced" for strip 41 by means of the adjusting screws 11.

The rear end of a string producing a tone which is too weak is lowered, or that of a string producing a tone which is too strong is raised, by means of its adjusting screw. After starting the voicing, if it is found that a string requires, for tone volume therefrom consonant with that of strings already voiced, to be lowered so much that a hard blow on its key 14 causes it to touch strip 41, the previously voiced strings may be re-voiced at a little higher position; or strip 41 may be slightly lowered. During these adjustments strip 42 should be in a low enough position to avoid any possibility of its being struck by any heavily vibrating strings.

Without disturbance of the now established position of strip 41, the position vertically of strip 42 may now be adjusted, with the movable contact of potentiometer 57 at its mid-point so that only translation effected by strip 42 now actuates the loudspeaker. Strip 42 should be secured in such a position that no heavily struck string quite touches it and so that the volume output of the loudspeaker is substantially uniform over the range of the instrument. A requirement of more critical adjustment than this for strip 42 will not be felt, owing to its greater spacing from the several strings than that of strip 41 (due to higher vibrational amplitudes nearer the center of the several strings) and to the previous rational adjustment of the positions of the several strings relative to each other effected in the voicing for string 41. If additional strips still forward of strip 42 be employed, as may of course be done for wider variation of tone quality, they may progressively be adjusted in the manner described for strip 42. Strips 41' and 42', employed with any strings 7 which may be overstrung, as shown in Figure 2, may be adjusted similarly and at the same time as strips 41 and 42, respectively. This method of voicing has the especial advantage of fully or at least largely compensating for irregularities in the efficiency at different frequencies of the loudspeaker 60 and other electrical apparatus in the system.

In Figures 1 and 3 we also show a tuning fork 71 insulatedly mounted as by insulating block 72 so that one of its prongs forms an electrical capacity with at least one of the metal strips 41 and 42 and that vibration of the fork will vary this capacity. The fork may be accurately ground to the proper frequency of one of the strings adjacent it, to which it may be wired. In tuning the instru-

ment both the fork and the string may be vibrated and the string tuned to the frequency of the fork, final accuracy being determined by the absence of beats in the output of loudspeaker 60. This method of establishment of absolute pitch in tuning is very convenient and effective, due to the generation of loud tone by both fork and string in the same medium—i. e., loudspeaker 60. The balance of the instrument may of course be tuned in the usual manner from this string as a basis. If desired, a whole consecutive octave or more of such forks may be provided each in association with the respectively pitched strings, for the further facilitation of tuning.

It will of course be understood that substitutions for and simplifications in the apparatus and circuits hereinabove disclosed may be made without departure from the scope or spirit of our invention, as hereinabove described or in the appended claims defined.

We claim:—

1. In a musical instrument, the combination of key-operated means for selectively vibrating a plurality of vibrators, having a plurality of keys and having two members associated with each key arranged to become and remain in contact with each other substantially immediately following original depression and during continued depression of said key; a vibrator-translator system comprising a tuned vibrator associated with each of said keys and apparatus for translating vibrations of said vibrators into electric oscillations; a source of electrical energy; and means individual to each of said vibrators for applying energy from said source to said vibrator-translator system, each of said individual means including a switch comprising an electrical contact on each of the said two contacting members associated with the respective said key.

2. In a musical instrument, the combination of key-operated means for selectively vibrating a plurality of vibrators, having a plurality of keys and having two members associated with each key arranged to become and remain in contact with each other substantially immediately following original depression and during continued depression of said key; a vibrator-translator system comprising a tuned vibrator associated with each of said keys and apparatus for translating vibrations of said vibrators into electric oscillations; a source of electrical energy; means individual to each of said vibrators for applying energy to said vibrator-translator system, each of said individual means including a reactive electrical circuit linking said source and one of said vibrators and a switch operatively connected therein, said switch comprising an electrical contact on each of said two contacting members associated with the respective said key.

3. In a musical instrument, including a plurality of tuned vibrators, including an action for selectively exciting such vibrators into vibration having a key for each of said vibrators and two members associated with each key arranged to become and remain in contact with each other substantially immediately following said vibrator excitation and during depression of said key, and including means for translating such vibration of each of said vibrators into electric oscillations: the combination of an electrical circuit associated with each of said vibrators for varying the efficiency of such translation of its vibration, and a switch connected in and operatively controlling each said circuit, each said switch comprising an electrical contact on each of the said two contacting members associated with the respective said key.

4. In a musical instrument, including a plurality of tuned vibrators, including an action for selectively exciting such vibrators into vibration having a key for each of said vibrators and two members associated with each key arranged to become and remain in contact with each other substantially immediately following said vibrator excitation and during depression of said key, and including means for translating such vibration of each of said vibrators into electric oscillations: the combination of an electrical circuit associated with each of said vibrators for varying the efficiency of such translation of its vibration, and a switch connected in and operatively controlling each said circuit, each said switch comprising a conductive surface on each of said two contacting members associated with the respective said key, and over at least one said conductive surface a compressible conductive element.

5. In a musical instrument, including a plurality of tuned vibrators, including a piano action for selectively exciting said vibrators into vibration having hammers, hammer back-checks, and members rigidly secured to said hammers and operatively engaging said back-checks, and including means for translating such vibrations of each of said vibrators into electric oscillations: the combination of an electrical circuit associated with each of said vibrators for varying the efficiency of such translation of its vibration, and a switch connected in and operatively controlling each said circuit, each said switch comprising as one element a conductive surface on the respective back-check and thereover a conductive leather strip, and as the other element a conductive surface on said member rigidly secured to the respective hammer and thereover a conductive leather strip.

6. In a musical instrument, including a plurality of electrically insulated vibrators,

including an action for selectively exciting such vibrators into vibration having a key for each of said vibrators and two members associated with each said key arranged to become and remain in contact with each other substantially immediately following said vibrator excitation and during depression of said key, including a source of d. c. potential, including at least one conductive element in spaced relation to and forming an electrical capacity with each of said vibrators, and including a resistance from each of said conductive elements to one terminal of said potential source; the combination of an electrical capacity connected between each said vibrator and said terminal of said potential source; a switch associated with each said key comprising an electrical contact on each of said two associated contacting members; an electrical capacity shunting each of said switches; a resistance connected from one side of each of said switches to the associated said vibrator; a resistance connected from the same side of each of said switches to some part of said d. c. potential source; and a connection from the other side of each of said switches to some part of said d. c. potential source.

7. In a musical instrument, including a plurality of electrically insulated vibrators, including an action for selectively exciting such vibrators into vibration having a key for each of said vibrators and two members associated with each said key arranged to become and remain in contact with each other substantially immediately following said vibrator excitation and during depression of said key, including a source of d. c. potential, including at least one conductive element in spaced relation to and forming an electrical capacity with each of said vibrators, and including a resistance from each of said conductive elements to one terminal of said potential source; the combination of a potentiometer having an adjustable member, said potentiometer shunting at least a portion of said source; an electrical capacity connected between each said vibrator and said terminal of said potential source; a switch associated with each said key comprising an electrical contact on each of said two associated contacting members; an electrical capacity shunting each of said switches; a resistance connected from one side of each of said switches to the associated said vibrator; a resistance connected from the same side of each of said switches to said adjustable member of said potentiometer; and a connection from the other side of each of said switches to some part of said d. c. potential source.

8. In a musical instrument, including a plurality of tunable vibrators, including a mechanico-electric apparatus for translating into electric oscillations vibrations of said vibrators, and including electro-acoustic

translating apparatus for translating such electric oscillations into sound: a tuning standard comprising at least one rigid vibrator tuned to the proper frequency of one of said tunable vibrators; means for translating vibration thereof into electric oscillations; and means for combining said last-mentioned oscillations with said first-mentioned oscillations.

9. In a musical instrument, including a case, including a frame therein, including vibrators secured to said frame, including an action, removable from said case, for selectively exciting said vibrators into vibration, and including mechanico-electric apparatus secured to said frame for translating into electric oscillations the vibrations of said vibrators: the combination of an individual electrical circuit for regulating the efficiency of such translation of the vibration of each vibrator, part of each said circuit being secured to said frame and part of each said circuit being disposed about said action; and an electrical connection between said two parts of each said circuit comprising a first conductive member insulatedly mounted to said frame, and a second conductive member mounted to said action and removably contacting with said first conductive member.

10. The combination of a frame; a plurality of strings strung therein; and means for translating vibrations of said strings into electric oscillations, said means including a strip of insulating material, means for mounting said strip to maintain one face thereof in spaced relation to a portion of each of said strings, and an electrically conductive member secured to said face.

11. The combination of a frame; a plurality of strings strung therein; and means for translating vibrations of said strings into electric oscillations, said means including a strip of insulating material, adjustable means for mounting said strip to maintain one face thereof in adjustable spaced relation to a portion of each of said strings, and an electrically conductive member secured to said face.

12. In a musical instrument, the combination of a frame; a pin-block of insulating material secured thereto; a tuning pin in said pin-block; a string having one end affixed to said tuning pin; means insulated from said frame for positioning said string near said end; an insulating member secured to said frame; an adjustable screw in said insulating member having therein a groove engaging said string; and a hitch pin insulated from said frame and securing the other end of said string.

13. In a musical instrument, the combination of a string; a support for said string; means for vibrating said string; at least one mechanico-electric translating device posi-

tioned adjacent said string for translating into electric oscillations the vibrations thereof; and means for adjusting the position of said string relative to said translating devices, said means comprising a screw rotatable in said support and a groove in said screw engaging said string.

14. In a musical instrument, the combination of a plurality of tuned vibrators; mechanico-electric translating apparatus in spaced relation to said vibrators for translating their vibrations into electric oscillations; and means, individual to and connected with each said vibrator, for selectively varying the positions of said vibrators to adjust their individual spacings from said translating apparatus, whereby the instrument may be voiced.

15. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating electric oscillations from said vibration; and means operative substantially immediately after the operation of said controlling means for reducing the efficiency of said translating means.

16. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating sound from said vibration; means operative in a predetermined time relationship to the operation of said controlling means for altering the efficiency of said translating means; and selective means for adjusting at least one of the characteristics of direction and degree of such alteration.

17. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating electric oscillations from said vibration; means operative in a predetermined time relationship to the operation of said controlling means for altering the efficiency of said translating means; and selective means for adjusting at least one of the characteristics of direction and degree of such alteration.

18. In a musical instrument of the type wherein tuned bodies are selectively vibrated and their vibrations translated by a mechanico-electro-acoustic translating system into electric oscillations and thence into sound, the method of adjusting the tone commencement characteristics, which consists in rendering substantially zero at the beginning of the vibration of each tuned body the efficiency of said translating system as to such body and in raising said efficiency thereafter.

19. In a key-operated musical instrument of the type wherein tuned bodies are selectively vibrated and their vibrations translated by a mechanico-electro-acoustic translating system into electric oscillations and thence into sound, the method of adjusting

the tone termination characteristics, which consists in reducing to substantially zero the efficiency of said translating system as to each body upon release of the therewith associated key.

20. In a key-operated musical instrument of the type wherein tuned bodies are selectively vibrated and their vibrations translated by a mechanico-electro-acoustic translating system into electric oscillations and thence into sound, the method of adjusting the tone commencement and termination characteristics, which consists in maintaining normally at a substantially zero value the efficiency of said translating system, in raising such efficiency as to each such tuned body upon depression of the therewith associated key, and in reducing said efficiency to said normal value upon release of said key.

21. In a musical instrument, the combination of a plurality of tuned bodies; a device associated with each of said bodies for exciting it into vibration; individual means for selectively operating said devices; means for translating the vibrations of said bodies into audible tones; and means, connected to and operated by each of said first mentioned means, for varying the efficiency of such translation of vibration of the associated said body.

22. In a musical instrument, the combination of a plurality of tuned bodies; a device associated with each of said bodies for exciting it into vibration; individual means for selectively operating said devices; at least one mechanico-electric system for translating into electric oscillations the vibrations of said bodies; and means, connected to and operated by each of said first mentioned means, for varying the efficiency of such translation of vibration of the associated said body.

23. In a musical instrument, the combination of a plurality of tuned bodies; means controlled by a key for vibrating each of said bodies; mechanico-electric apparatus for translating into electric oscillations the vibrations of said bodies; and an individual electric circuit associated with each body for regulating the efficiency of such translation of the vibration of said body, each said circuit including a switch operatively associated with the corresponding said key.

24. In a musical instrument, the combination of a plurality of tuned bodies; means controlled by a key for vibrating each of said bodies; mechanico-electric apparatus for translating into electric oscillations the vibrations of said bodies; and an individual electric circuit associated with each body for regulating the efficiency of such translation of the vibration of said body, each said circuit including electrical reactance, and a variable element operatively associated with the corresponding said key.

25. In a musical instrument, the combination of a plurality of tuned, electrically conductive bodies; means controlled by a key for vibrating each of said bodies; at least one electrically conductive member forming an electrical capacity with a vibratable portion of each of said bodies; means for establishing a d. c. potential difference between said conductive members and each of said bodies; and means operatively associated with each said key for varying such potential difference between said conductive members and the said body associated with said key.

26. A musical instrument comprising an oscillator, an electric circuit excited by said oscillator, and means associated with and influencing the excited circuit for eliminating such excitation thereof during a predetermined oscillation range of said oscillator.

27. A musical instrument comprising a mechanical oscillator, and electric circuit excited by said oscillator, and means associated with and influencing the excited circuit for eliminating such excitation thereof during a predetermined oscillation range of said oscillator.

28. A musical instrument comprising an oscillator, an electric circuit excited by said oscillator, and means associated with and influencing the excited circuit for modifying the degree of such excitation thereof during a predetermined oscillation range of said oscillator.

29. A musical instrument comprising a mechanical oscillator, an electric circuit excited by said oscillator, and means associated with and influencing the excited circuit for modifying the degree of such excitation thereof during a predetermined oscillation range of said oscillator.

30. A plurality of oscillators, an electric circuit excitable by said oscillators, selective means individual to each said oscillator for establishing excitation of said circuit thereby, and means also individual to each said oscillator, and associated with and influencing said circuit, for modifying the degree of such excitation over a predetermined period following operation of the associated said selective means.

31. A plurality of mechanical oscillators, an electric circuit excitable by said oscillators, selective means individual to each said oscillator for establishing excitation of said circuit thereby, and means also individual to each said oscillator, and associated with and influencing said circuit, for modifying the degree of such excitation over a predetermined period following operation of the associated said selective means.

32. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating sound from said vibration; and means

operative in a predetermined time relationship to the operation of said controlling means for altering the efficiency of said translating means.

5 33. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating electric oscillations from said vibration; and means operative in a predetermined time relationship to the operation of said controlling means for altering the efficiency of said translating means.

10 34. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating electric oscillations from said vibra-

tion; and means operative in a predetermined time relationship to the operation of said controlling means for increasing the efficiency of said translating means.

35. In a musical instrument, the combination of a tuned vibrator; means for controlling the vibration thereof; means for translating electric oscillations from said vibration; means operative in a predetermined time relationship to the operation of said controlling means for varying the efficiency of said translating means; and means for eliminating at will the action of said varying means.

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DISCLAIMER

1,915,859.—*Benjamin F. Miessner*, Millburn Township, Essex County; and *Charles T. Jacobs*, Chatham Borough, N. J. METHODS AND APPARATUS FOR THE PRODUCTION OF MUSIC. Patent dated June 27, 1933. Disclaimer filed March 15, 1939, by the assignee, *Miessner Inventions, Inc.*

Hereby enters its disclaimer to the combination claimed in claim 30 in said Letters Patent, excepting wherein the recited means for modifying the degree of the recited excitation over the recited period comprises means for reducing the degree of said excitation during said period.

[*Official Gazette April 4, 1939.*]

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