June 27, 1933. B. F. MIESSNER ET AL 1,915,860

METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Original Filed May 20, 1931 4 Sheets-Sheet 1

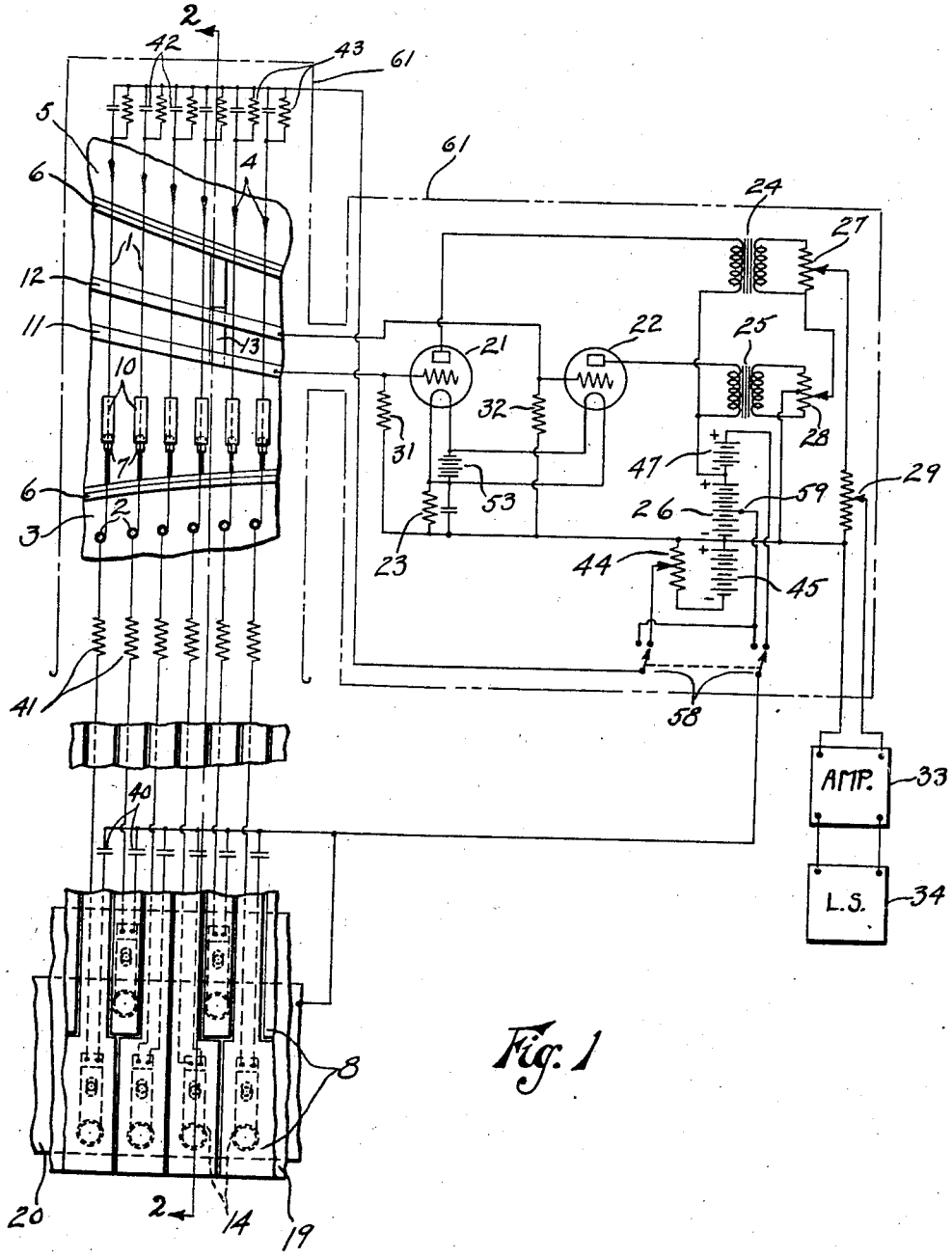


Fig. 1

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Original Filed May 20, 1931 4 Sheets-Sheet 2

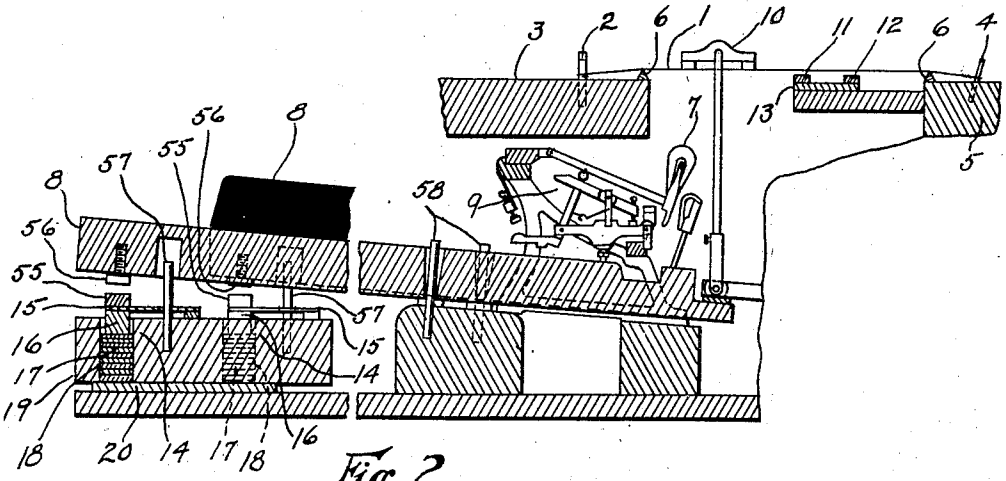
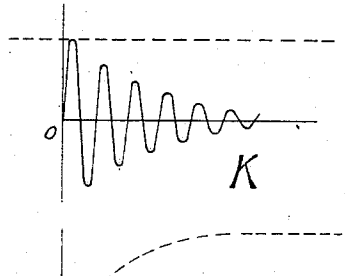
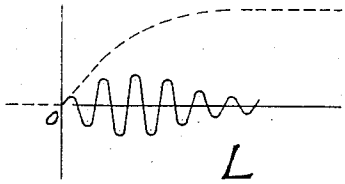
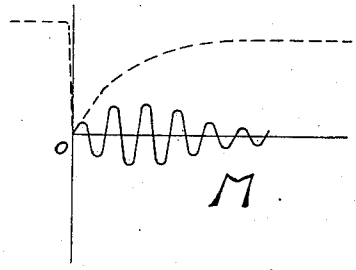


Fig. 2







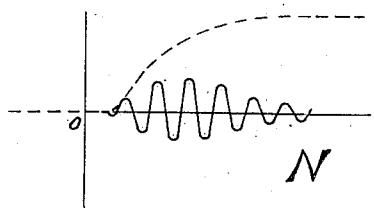


Fig. 6

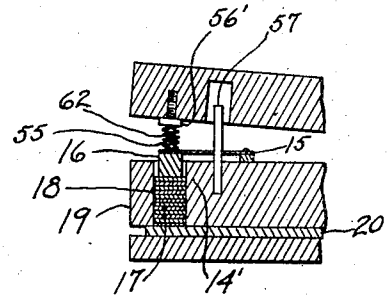


Fig. 4

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METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Original Filed May 20, 1931 4 Sheets-Sheet 3

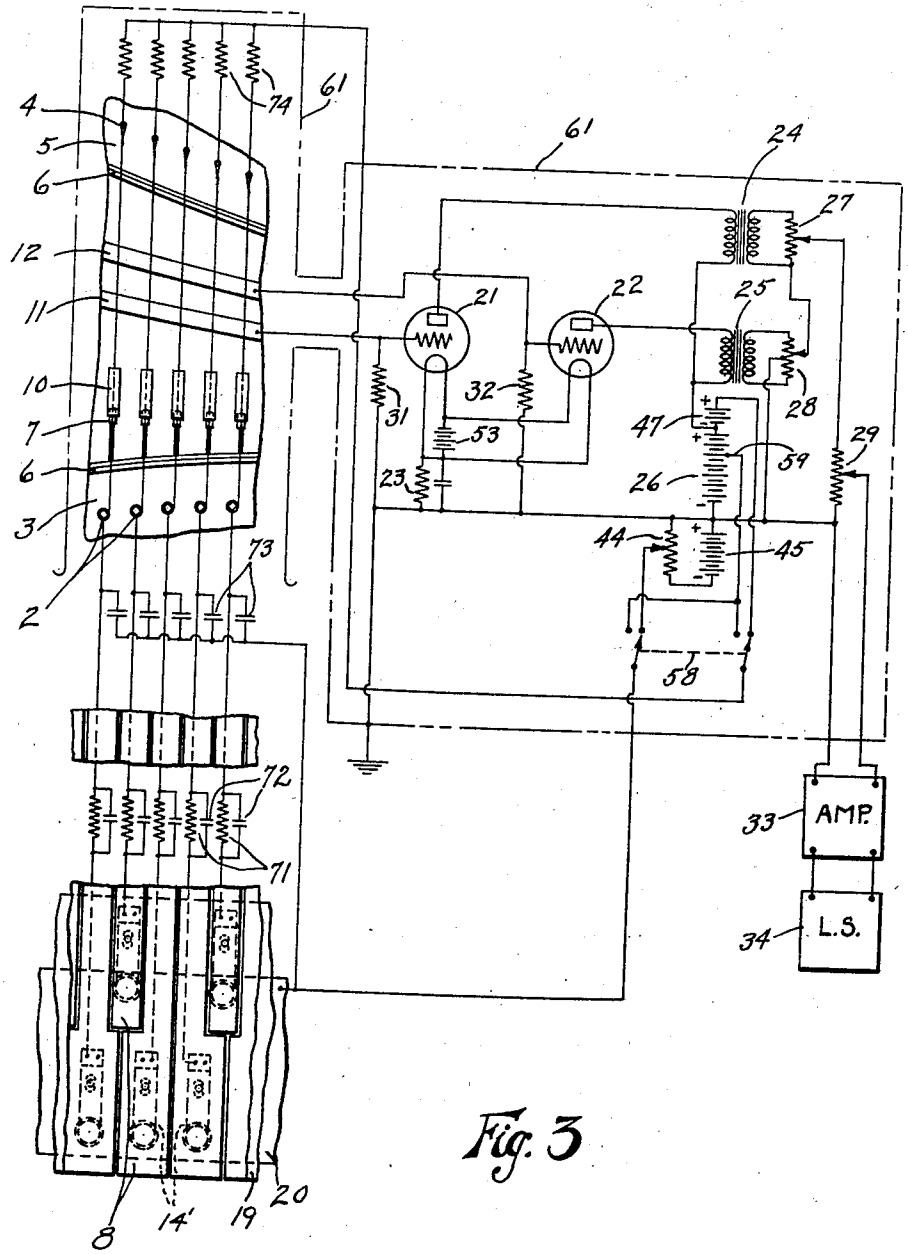


Fig. 3

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METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Original Filed May 20, 1931 4 Sheets-Sheet 4

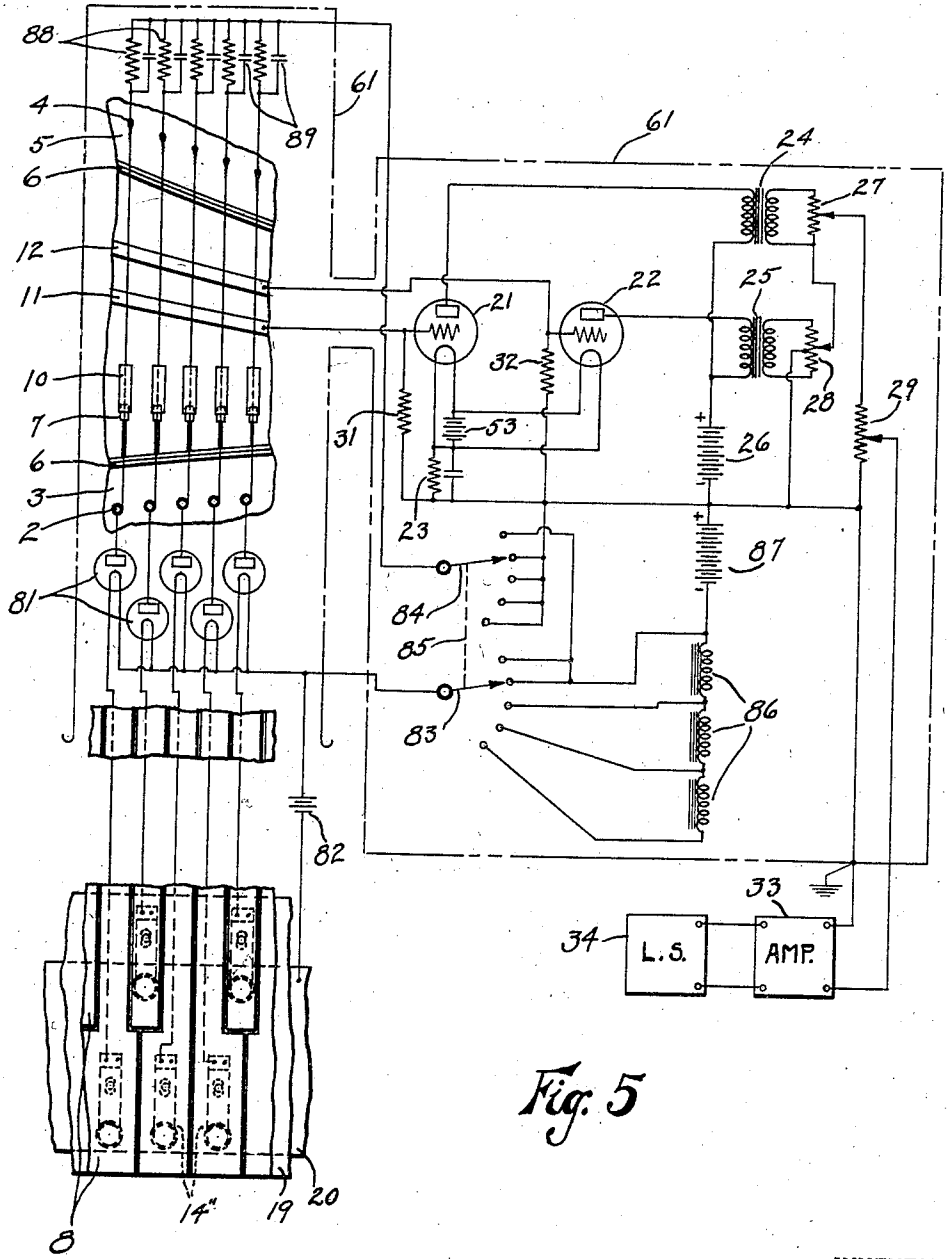


Fig. 5

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UNITED STATES PATENT OFFICE

BENJAMIN F. MIESSNER, OF MILLBURN TOWNSHIP, ESSEX COUNTY, AND CHARLES T. JACOBS, OF NEW PROVIDENCE TOWNSHIP, UNION COUNTY, NEW JERSEY, ASSIGNORS TO MIESSNER INVENTIONS, INC., A CORPORATION OF NEW JERSEY

METHOD AND APPARATUS FOR THE PRODUCTION OF MUSIC

Application filed May 20, 1931, Serial No. 538,773. Renewed May 21, 1932.

This invention relates to musical instruments and systems wherein the vibrations of tuned bodies are translated into electric oscillations and such oscillations employed for the actuation of further apparatus; and more particularly to the control of the amplitude-time characteristics of the musical tones thereby produced. The invention, although useful with any form of tuned body and with any mode of excitation thereof, is illustrated in connection with strings caused to vibrate by percussion. Instruments of the class described and improvements therein have 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.

The herein described invention is concerned primarily with the control, adjustment and variation of the initial and early amplitude-time characteristics of the musical tones electrically produced by such instruments, including the reduction or elimination of initial high amplitude; and also with the rate of damping of the tones upon release of the key in a key-operated musical instrument of the class described. Thus, for example, by the employment of the present invention in one of its forms the tones of an instrument otherwise generally piano-like in their amplitude-time characteristics may be stripped when desired of their percussion-produced attribute of high initial amplitude and thereby rendered organ-like. A key-operated, piano type of electrical musical instrument, thus made when desired or at all times to simulate an organ, possesses the marked advantage over the latter of the control of the general amplitude of individual tones resulting from the many possible different manners of depression of the several keys, or the "touch" as it is musically termed, which is of course of no significance in the playing of a conventional organ. Our invention furthermore may make available tremolo effects of individual tones, an availability not present in the usual organ.

Thus it is an object of our invention to provide, in a musical instrument or system of the class described, methods and apparatus for reducing or eliminating a high initial output tone amplitude; and it is a further and allied object to provide methods and apparatus for delaying until appreciably after commencement of a tone the instant of maximum amplitude thereof; and a still further and allied object is the provision of methods and apparatus for delaying after key depression the commencement of the tones produced by a key-operated instrument of the class described. Another object is the provision of methods and apparatus for controlling the rate of damping upon key release of the tones produced by a key-operated instrument of the class described; and still another object is the provision of means and methods for effecting a "tremolo" of any tone or any one or more of a plurality of tones being produced at any time by such an instrument.

It is a further object to provide an 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 a specific object to provide an electrical, key-operated musical instrument possessing simultaneously all or any of the following characteristics; selective availability of different tone qualities, selective availability of different amplitude-time characteristics, ability to produce tremolo effects of individual tones, and responsiveness to manner of key depression, or "touch". Other and allied objects will more fully appear from the following specification and the appended claims.

The general principle involved in our invention is that of varying the efficiency of translation into electric oscillations of the vibrations of the several tuned bodies, such variation being coincidentally produced with the manipulation of the key or other control of the vibration, in such a manner as for example to provide low or zero efficiency at

the beginning of the vibration. This novel basic method of adjustment and control of the amplitude-time characteristics of musical tones is capable of modification and enlargement, and of being carried out by a variety of combinations of apparatus, as hereinafter more fully appears.

In the detailed description of our invention, hereinafter set forth, reference is had to the accompanying drawings, of which:—

Figure 1 is a view, partly plan and partly schematic, of a portion of a musical instrument embodying our invention in one form;

Figure 2 is a vertical cross-sectional view, taken along line 2—2 in Figure 1, in which certain further mechanical details appear;

Figure 3 is a view, similar to Figure 1, illustrating a modification of our invention;

Figure 4 is a vertical cross-sectional view, similar to Figure 2, illustrating a detail of the modification shown in Figure 3;

Figure 5 is a view, similar to Figures 1 and 3, illustrating a further modification of our invention; and

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

In Figure 1 we show, partly schematically, a musical instrument embodying our invention in one form. In this figure will be seen a plurality of strings 1, strung between tuning pins 2 in insulating front plank 3 and pins 4 in insulating rear member 5, over insulating triangular bars 6 to limit the active vibratory portion thereof. A hammer 7 may be provided under each string to vibrate the latter. Each hammer 7 may be actuated by a key 8 through the medium of a repeating action 9, shown in Figure 2, a vertical cross-sectional view taken along the line AA in Figure 1; such an action is well known as a component of the grand piano. A damper 10, also actuated by key 8, may be provided for each string if desired. The keys may be pivoted as at 58 and held in lateral alignment at the front by guide pins 57, as will be understood.

Washers about lateral guide pins 57, customarily employed for limiting the downward motion of the front of keys 8, are omitted; and their function is performed by components 56, 55, 15, 16 and 17. Thus 17 may be a pile of thin, circular, high-resistance graphite or similar discs, each pile bottoming on a common electrically conductive plate 20; 16 may be an electrically conductive button or plunger affixed to the bottom of an electrically conductive spring 15 and by the latter held with light pressure against the top of pile 17; 55 may be a felt button affixed to the top of spring 15; and 56 may be an adjusting screw in the bottom of key 8, hex-headed for example. Piles 17 may rest on plate 20 in holes 18 in front bar 19, which may be of non-conductive material and to which may be mounted springs 15. Depression of the front end of key 8 will thus be seen to be limited by the resulting compression of pile 17.

In order to translate the vibrations of the strings 1 into electric oscillations, a capacity may be formed between each string and a bar 11 and a bar 12, such bars being insulatedly mounted underneath the strings on insulating blocks 13. Each of these bars may be connected to the grid of a thermionic vacuum tube, such tubes being shown as 21 and 22 respectively in Figure 1. The cathodes of these tubes may be energized by battery or other current source 53; and their grids may be biased negatively with respect to their cathodes, through resistors 31 and 32 respectively, by the flow of their anode current through condensively by-passed resistor 23, as will be understood. In the output circuits of these tubes may be provided transformers 24 and 25, respectively; and a common battery or other anode current source 26 may be employed for the two tubes. Across the secondary of transformer 24 may be provided potentiometer 27 and across the secondary of transformer 25 center-tapped potentiometer 28. A variable portion of each of these two potentiometers may form a series circuit with the entire resistance of potentiometer 29 as shown; and between the variable contact and one end of the resistance of potentiometer 29 may be connected the input of an electrical amplifier 33, to the output of which may be connected loudspeaker or other electro-acoustic translating device 34. Electrostatic shielding 61 may advantageously be provided about the tubes 21 and 22 and their associated apparatus, about the leads to their grids, and partially about the strings 1, bars 11 and 12, etc.

In order to make the capacities formed between the several strings 1 and the bars 11 and 12 effective in translating the string vibrations into electric oscillations, a potential difference must be established between the strings and such bars. This is accomplished for any string whose associated key 8 is depressed by an electrical circuit including the pile 17, plunger 16 and spring 15 associated with the particular key. Such a pile, plunger and spring will be recognized by those skilled in the art as constituting a resistance whose value varies according to the pressure exerted on pile 17 by plunger 16 and will hereinafter be referred to as variable resistance 14: it will thus be understood that there is associated with each key a resistance, normally high, which is reduced to a relatively low value by the last portion of the depression of the key.

Each string 1 may be wired to its associated spring 15—i. e., to one side of its associated variable resistance 14—through a resistor 41; and each variable resistance 14

may be by-passed by a condenser 40 connected between such spring and the common side of all the variable resistances. This common side may be connected to a point of different potential than bars 11 and 12; and this point may conveniently be a point of positive potential in battery or source 26 or a point rendered still more positive by an additional battery or source such as 47. Each string is further connected, through a capacity 42 and a resistor 43 in parallel, either to a point of the same mean D. C. potential as that of the bars 11 and 12 or preferably to a point of slightly more negative potential, as to the movable contact of a potentiometer 44 shunting a battery or source 45 in series with the negative terminal of 26.

Consideration being given to the manner of functioning of the apparatus shown, it will be seen that, unless the variable resistance 14 be infinite when key 8 is in its normal or raised position, current will flow from the positive terminal of battery or source 47 through each pile 17, associated plunger 16 and spring 15, and associated resistors 41 and 43 to the negative terminal of battery or source 26 or. as shown, to a point of more negative, adjustable potential—i. e., the slider of potentiometer 44. With all keys in their normal position it is desirable so to adjust this potential that the voltage drop across each resistor 43 approximately equals that across the upper-shown half of potentiometer 44, thus rendering the potential of the several strings 1 at least approximately the same as that of the negative terminal of battery 26 and hence as that of the bars 11 and 12. The degree of this approximation depends on the accuracy of this adjustment and on the uniformity each between themselves of the normal resistances of the several variable resistances 14, of the values of the several resistors 41, and of the values of the several resistors 43. Under these circumstances, therefore, were the string to vibrate, little or no translation of its vibration into electric oscillations would take place.

Upon depression of any key 8, not only is the associated damper 10 lifted from and hammer 7 caused to strike string 1, but the resistance of the associated variable resistance 14 is reduced, tending to raise the mean D. C. potential of string 1 and thus to make the capacities between string 1 and bars 11 and 12 effective in translating string vibration into oscillations, as will be understood. Due to the time required for condenser 40 to reduce its charge and for condenser 42 to increase its charge, however, the potential of string 1 cannot change in the practically instantaneous manner in which the resistance 14 is changed. The translation efficiency therefore rises slowly from its low or zero value to its new value. By suitable choice of the values of the several components the rate of rise of translation efficiency may be nicely adjusted. Upon release of key 8 and consequent raising of the value of resistance 14, the original conditions are restored, also gradually rather than abruptly, at a rate also determined by the values of the components.

The vibration-produced variation of the capacity between string 1 and each of the bars 11 and 12 will cause such potential as exists between the string and each of the bars to vary; and thus there is produced across each of resistors 31 and 32 an A. C. voltage substantially corresponding in its characteristics, including harmonic structure, to the vibration of the mean string point opposite the respective bar. This action is similar to that of the well-known condenser microphone; and the amplitude of the voltages across resistors 31 and 32 at any instant will be seen to be a function of the mean potential difference between the string and the bars. Thus to such extent as this potential is delayed in rising to full value, the efficiency of translation of the string vibration into electric oscillations is delayed in its rise from zero to normal value.

The A. C. voltages appearing across resistors 31 and 32 are amplified respectively by tubes 21 and 22 and transformers 24 and 25, and appear across respective potentiometers 27 and 28. From these potentiometers such voltages, each regulable in amplitude and that across center-tapped potentiometer 28 regulable in phase with respect to that across potentiometer 27, may be applied to potentiometer 29; and from this potentiometer a composite voltage of regulable amplitude may be applied to and amplified by electrical amplifier 33, the output of which is translated into sound by loudspeaker 34.

One of the bars 11 and 12, one of the tubes 21 and 22, one of the transformers 24 and 25, and both the potentiometers 27 and 28 may be omitted, 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 of the vibrations of the mean string points opposite the two bars 11 and 12, the consequent difference in harmonic composition of the voltages across resistors 31 and 32, 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 27 and 28. The number of such separate translating systems need not of course be limited to two, such number being only illustrative herein.

Reference again being had to the electrical

system associated with each separate key and string, it will be seen that this system comprises a variable resistance 14 shunted by a capacity 40, a fixed resistor 41, and a capacity 42 and resistor 43 in parallel. The variable resistance 14 and shunting capacity 40 may be replaced if desired by a simple key-operated make-and-break switch, the desired delay action still being produced by the time required to charge condenser 42 through resistor 41. We have found, however, that the opening and closing of a simple switch almost invariably produces objectionable "clicks" in the output of loudspeaker 34 and therefore prefer to employ a gradually-acting switch, such as 14 may be considered. Even in this case some undesirable noise may be experienced upon depression and/or rise of the key and we therefore prefer to include the shunting condensers 40, which we have found helpful in eliminating such noise. If the switch consists, as shown, of a variable resistance, and if this resistance has an appreciable minimum value, resistor 41 may be omitted. Again, a fixed resistor may be substituted for the switch or variable resistance, and resistor 43 replaced by a key-operated switch or variable resistance, of normally zero or low resistance and of high or infinite resistance upon key depression; or a potentiometer may be substituted for each resistor 41 and its associated switch or variable resistance 14, key 8 controlling the position of the movable contact, and a condenser 40 connecting such contact to one end, of each such potentiometer. It will be appreciated that these and other modifications of the circuit shown may be made by those skilled in the art, according to convenience and required degree of freedom from extraneous noise accompanying the music produced by the system; and that these modifications will not constitute departures from the spirit or scope of our invention, which in this form embraces broadly the use of electrical reactance and resistance to produce a time lag in a change of translating efficiency caused by key depression.

In general when all the elements shown are present, we prefer to employ resistances very roughly of the same order of value for 41 and 43 and a variable resistance 14 whose resistance is varied by key depression from many times such value to a fraction thereof. We have found it desirable to employ as small a capacity across the variable resistance 14 as is effective in eliminating or minimizing noise production thereby; and to adjust the rate of change of translation efficiency principally by choice of value of capacity of condenser 42. Thus, assuming other parameters to be fixed and condenser 40 to have negligible delaying effect, if condenser 42 be of relatively low capacity the rise of translation efficiency upon key depression will be rapid and little difference will be produced from the ordinary case in which translation efficiency is maintained at all times; if the capacity of condenser 42 be of somewhat larger value, a somewhat slower rise of efficiency will take place and the tones produced by the instrument will be appreciably less piano-like in their inception; if relatively large capacities be used for condenser 42, the rise of efficiency will be quite slow, resulting in obliteration of the usual effect of percussion excitation or even in the creation of the opposite effect of a slow crescendo at the beginning of each tone.

It will be understood, of course, that the rate of efficiency rise can be decreased, with a given capacity of condenser 42, by change of other elements—i. e., by increase of capacity 40, of the value of resistor 41, etc.—and further that appreciable differentiation between rising and falling rates, upon key depression and release respectively, may be made by adjustment of the relative values of resistors 41 and 43. Variation of the relative values of the resistors and the minimum value of the variable resistance 14 will affect the potential across the string-bar capacities under conditions of key depression and hence will affect the maximum available translation efficiency; this may of course be compensated if desired by change of the total voltage applied across the resistors by sources 47, 26 and 45. In any particular case and for the production of any particular effect both the relative and the absolute values of the components may readily be determined by test, with the aid of the principles above enunciated.

In Figure 1 we also show a double pole, double throw switch 58, the poles of which have been assumed in the right-hand position, as shown, in the foregoing description. If, however, the poles of switch 58 be thrown to the left hand position, the system associated with each key which includes the variable resistance 14, the fixed resistors 41 and 43, the condensers 40 and 42, and the string 1, will be rendered at a uniform potential and free of current flow therein; and, by virtue of connection to point 59 in source 26 or source 47, at a potential different from that of the bars 11 and 12. Under these circumstances the delay action is cut out, a constant translating efficiency being maintained at all times and being susceptible of equalization with the maximum translating efficiency of the delay action condition by suitable choice of the potential of point 59. Thus by the inclusion of switch 58 we provide an instrument, the early amplitude-time characteristics of whose tones may be altered at will.

The delay action in the instrument shown in Figures 1 and 2 is produced by rendering translation efficiency normally small or absent and in causing it to increase upon key

depression. It is equally possible to produce such action by permitting translation efficiency to be high at all times excepting momentarily upon key depression. Thus in Figures 3 and 4 we show a musical instrument generally similar to that shown in the preceding figures, but modified therefrom in this respect. Thus the strings 1 and their supports, etc., hammers 7, keys 8, action 9, dampers 10, guide pins 57, etc., may be provided as in Figures 1 and 2; also the bars 11 and 12, vacuum tubes 21 and 22, and their immediately associated circuits, transformers 24 and 25, potentiometers 27, 28, 29 and 44, batteries or sources 47, 26 and 45, amplifier 33, loudspeaker 34, switch 58 and shielding 61. Switches or variable resistances 14′ may be provided, being seen in Figure 4 to differ from the component 14 in Figures 1 and 2 only in the inclusion of springs 62 and in the use of an adjusting screw 56′ which may be provided with a protrusion to hold spring 62 in place.

In Figure 3, however, each string 1 is wired to the spring 15 of its associated switch or variable resistance 14′ through a resistor 71 shunted by a condenser 72; and each string may be provided with a capacity 73 to the common side of the variable resistances 14′. This common side may be connected to the movable contact of potentiometer 44. Each string may also be connected through a resistor 74 to the positive terminal of battery or source 47 or other point of substantially different potential from that of bars 11 and 12.

The general manner of functioning of the apparatus shown in Figures 3 and 4 is similar to that disclosed above for Figures 1 and 2, the outstanding exception being, of course, that of the individual circuits associated with the several strings 1. It will be seen that, unless the value of the variable resistance 14′ be infinite when key 8 is in its normal or raised position, current will flow from the positive terminal of battery or source 47 through each of the resistors 74 and through the associated resistor 71 and the associated variable resistance 14′. If the resistors 71 be of a larger order of value than resistors 74, and if the maximum value of the variable resistances 14′ is of a still larger order, as we prefer to arrange these values, the condensers 73 will be charged to almost the full potential of the sources 47, 26 and 45. The string-to-bar potentials will be seen to be equal to the potentials across condensers 73 less the potential across the upper-shown portion of potentiometer 44, and translation efficiency is therefore being maintained. At the same time a relatively low potential appears across condensers 72.

Upon depression of any key 8, however, not only is the associated damper 10 lifted from and hammer 7 caused to strike string 1, but the value of the associated variable resistance 14′ is reduced, preferably to a value negligible in comparison to resistors 74 and 71. Thus condenser 72 is effectively paralleled with condenser 73; and if the capacity of 72 be many times that of 73, as we prefer to make it, a large percentage of the charge normally present in condenser 73 will pass out therefrom into condenser 72, causing the voltage across condenser 73 to drop almost to the relatively low voltage originally present across condenser 72. Current will immediately begin to flow through resistor 74 into condensers 72 and 73 and will raise the potential across them; but a time elapses before a high value of such voltage is reached, depending principally on the value of resistor 74 and the combined capacities of condensers 72 and 73. Upon release of key 8 and consequent raising of the value of variable resistance 14′, the original conditions are restored, the high voltage across condenser 72 being reduced to the original voltage by discharge of the condenser through resistor 71.

In the case of Figures 1 and 2, it is desirable that the switch or variable resistance 14 be closed or reduced in value as late in the key stroke as possible. The converse is true in the case of Figures 3 and 4: hence the provision of spring 62. By virtue of this spring the first downward motion of key 8 is caused to exert pressure on pile 17; spring 62 at or near the end of the stroke, and after compression of pile 17, compressing sufficiently for the protrusion on screw 56′ to bottom on felt button 55. Thus the drop of translation efficiency caused by depression of key 8 may be caused so to take place that the efficiency will have been rendered low at the time of the impact of hammer 7 with string 1. Residual efficiency at this instant, due to the residual voltage across condenser 73, may be minimized or eliminated by adjusting the slider of potentiometer 44 so that the voltage across its upper-shown portion approximately equals such residual voltage, rendering small or zero the potential at this instant between string 1 and bars 11 and 12.

As in Figure 1, we show in Figure 3 a switch 58 for removing potential differences from the individual circuits associated with the several strings and comprising resistors 74 and 71, condensers 73 and 72, and variable resistances 14′; and for establishing these circuits and all their components, including strings 1, at a fixed potential with respect to bars 11 and 12. It will be understood, of course, that the circuits and apparatus shown in Figure 3 are capable of modification within wide limits by those skilled in the art, without departure from the novel method of rendering translation efficiency momentarily low or absent at the time of inception of vibra-

tion, or of impact of hammer with string.

In Figure 5 we shown our invention in another modified form, in which translation efficiency is normally low or absent and is raised by key depression as in Figures 1 and 2, but in which modified circuits are employed. The instrument may be largely similar to that of preceding figures. Thus the strings 1 and their supports, etc., hammers 7, keys 8, action 9, dampers 10, guide pins 57, etc. may be provided as in Figures 1 and 2; also the bars 11 and 12, vacuum tubes 21 and 22 and their immediately associated circuits, transformers 24 and 25, potentiometers 27, 28 and 29, battery 26, amplifier 33, loudspeaker 34 and shielding 61. Switches or variable resistances 14'' may be provided; of similar form to those of Figure 1, but having piles 17 of much lower resistance, suitable for the control, from extremely low to normal value, of the filament current of two-element vacuum tubes 81, of which one is provided for each string.

In Figure 5 each string is seen to be wired to the plate of its associated tube 81. The filament of each of these tubes is maintained in a practically extinguished, substantially non-emitting condition by the normal or maximum resistance value of the variable resistance or switch 14'' connected to one side thereof, the common side of the variable resistances or switches 14'' being connected through filament battery or current source 82 to the other side of each of the filaments. One side of each of the filaments is also connected to the pole 83 of double-pole tap switch 85, whereby it may be connected through a selectable inductance to a point of lower D. C. potential than that of bars 11 and 12. Such selectable inductance may be provided by a plurality of choke coils 86 or by a single, tapped, high inductance choke coil; and such point of low D. C. potential may be the negative terminal of a battery or source 87. Each string 1 may also be connected to pole 84 of switch 85 through a resistor 88 and a condenser 89 in parallel. Switch 85, in its several positions excepting the up-most one as shown, will apply the potential of battery or source 87 across the individual circuits comprising tubes 81, strings 1, resistors 88 and condensers 89, through an inductance whose value depends on the setting of the switch; in its upmost position it applies no potential to such circuits, but establishes them at a uniform negative potential with respect to bars 11 and 12.

Again the general manner of functioning of the apparatus is as heretofore described, with the exception of the delaying circuits. With any key in its normal or raised position the plate-to-filament resistance of its associated tube 81 is infinite or practically infinite, so that substantially no current flows therethrough from battery or source 87 and no voltage drop occurs in resistor 88. Thus string 1 is at the same D. C. potential as bars 11 and 12 and translation efficiency is absent. Upon depression of any key 8, however, not only is the associated damper 10 lifted from and hammer 7 caused to strike string 1, but the resistance value of the associated switch or variable resistance 14'' is reduced to a value permitting normal filament current for tube 81. The plate-to-filament resistance of this tube is thus rendered finite and current flows from battery or source 87 through resistor 88, tube 81, and such inductance as may be placed in the common circuit by the pole 83 of switch 85. The voltage produced by the flow of this current through resistor 88 appears between string 1 and bars 11 and 12, making the capacities therebetween effective in translating string vibration into electric oscillations.

It will be appreciated that three factors other than switch or variable resistance 14'' operate to delay the rise of potential between string 1 and the bars: the time required for the filament of tube 81 to reach normal emitting condition after completion of its filament circuit, the time required to charge condenser 89, and the time required for the current through the inductance to change. These factors need not all be simultaneously present: thus condensers 89 may be omitted; or they may be employed, for the purpose of rendering strings 1 at a low effective A. C. potential, of a small value producing negligible delaying effect. Again the inductance 86 may be omitted; or it may be employed in a single instead of a variable value.

The filament material and design of tube 81 may be variously chosen to produce negligible or large delay in reaching emitting condition after completion of the filament circuit, as may be desired. If material of high thermal inertia be employed, it will be seen that not only the attainment to full value of translating efficiency, but also the inception of the rise thereof from the normal low or zero value, may be delayed for a definite period after excitation of the string 1.

With any of the arrangements hereinabove set forth, tremolo effects on any individual tone may be secured by the performer by a succession of incomplete releases and re-depressions of the key, after original depression. Such tremolos are of course, limited in rapidity by the rate of change of translation efficiency with change of key position which results from the values of the various components employed in a particular case.

When translation efficiency is normally maintained at a negligible or zero value and is raised only upon key depression, as is possible with the arrangements of Figures 1 and 5, the mechanical dampers 10 may, if desired, be omitted or permanently raised from the strings; cessation of the tones pro-

duced by string vibration then being effected entirely by the drop to zero value of translation efficiency upon key release. As above indicated, the rate of drop of efficiency in the case of Figure 1 is determined largely by the relation of condenser 42 to resistor 43; and the rate of drop in the case of Figure 5 is determined by the characteristic of the drop of emission of tube 81 upon extinguishment of its filament, the inductance employed as 86 and the relation of condenser 89, if employed, to resistor 88. Thus by control of the relations of the components, not only may initial amplitude-time tone characteristics be controlled, but also the terminal of such characteristics.

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 K may represent a normal case wherein translation efficiency is maintained at all times. Curve L may represent oscillations produced in the apparatus shown in Figures 1 and 2, wherein translation efficiency is normally low or, as shown, zero and begins to rise coincidentally with vibrator excitation. Curve M may represent oscillations produced in the apparatus shown in Figures 3 and 4, wherein translation efficiency is normally high but is reduced to a low or, as shown, zero value at or just before excitation. Curve N may represent oscillations produced in the apparatus shown in Figure 5, wherein translation efficiency is normally low or, as shown, zero and begins to rise at a definite time after excitation, due, for example, to the employment of tube filaments of high thermal inertia. It will be understood that these curves are illustrative only, and are susceptible of modification in 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.

We claim:

1. In a musical instrument of the type wherein tuned bodies are selectively vibrated and their vibrations translated into electric oscillations and thence into sound, the method of variously establishing the tone commencement characteristics, which consists in provoking a variation of the efficiency of such translation of vibration of each body coincidentally to the starting of such vibration, and in selectively adjusting the rate of such variation.

2. In a musical instrument, the combination of a plurality of tuned bodies; individual means associated with each of said bodies for exciting it into vibration; at least one mechanico-electric system for translating into electric oscillations the vibrations of said bodies; means connected to and coacting with each of said first-mentioned means, for varying the efficiency of such translation of vibration of the associated said body; and selective means for adjusting the rate of such efficiency variation.

3. 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 variable element connected with the corresponding said key, said element being variable in accordance with pressure on said key.

4. 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 device characterized by thermal inertia and means operatively associated with the corresponding said key for regulating the passage of an electric current through at least a portion of said device.

5. In a musical instrument, the combination of a plurality of tuned, electrically conductive bodies; a device actuated by a key for

exciting each of said bodies into vibration; at least one electrically conductive member, each said member forming an electrical capacity with a vibratable portion of each of said bodies; a resistance from each of said electrically conductive members to a point of fixed D. C. potential; means for causing variations in said capacities to produce voltages across said resistances, said means including a source of D. C. potential containing the potential of said point, an individual system of series resistances for each of said bodies shunting said source, and a connection from each of said bodies to a point in its associated said resistance system; and individual automatic means for varying the efficiency of said first-mentioned means in a definite manner, said automatic means including a variable element in each said resistance system, operatively connected to the associated said key, and at least one electrical capacity associated with each said resistance system.

6. In a musical instrument, the combination of a plurality of tuned, electrically conductive bodies; a device actuated by a key for exciting each of said bodies into vibration; at least one electrically conductive member, each said member forming an electrical capacity with a vibratable portion of each of said bodies; a resistance from each of said electrically conductive members to a point of fixed D. C. potential; means for causing said vibrations of said bodies to produce voltages across said resistances, said means including a source of D. C. potential, a plurality of two-element vacuum tubes, the anode of each such tube being connected to a different one of said bodies, a source of filament current for all of said tubes, a connection from said filament source to the negative terminal of said D. C. potential source, and a resistance from each of said bodies to said point of fixed potential; and individual automatic means for varying the efficiency of said first-mentioned means in a definite manner, said automatic means including a device for controlling the filament current of each said tube, operatively connected to the associated said key.

7. In a musical instrument, the combination of a plurality of tuned bodies; a device actuated by a normally raised key for exciting each of said bodies into vibration; a pile of thin discs of resistance material underneath each key arranged to limit, by compression of said pile, a downward stroke of the associated said key; and electrical connections to the extremities of said pile whereby said pile is made effective as a variable electrical resistance.

8. 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 selective means for adjusting the rate of such variation.

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