Aug. 1, 1961 B. F. MIESSNER 2,994,239

TUNED-VIBRATOR MUSICAL INSTRUMENT

Original Filed Feb. 1, 1955 2 Sheets-Sheet 1

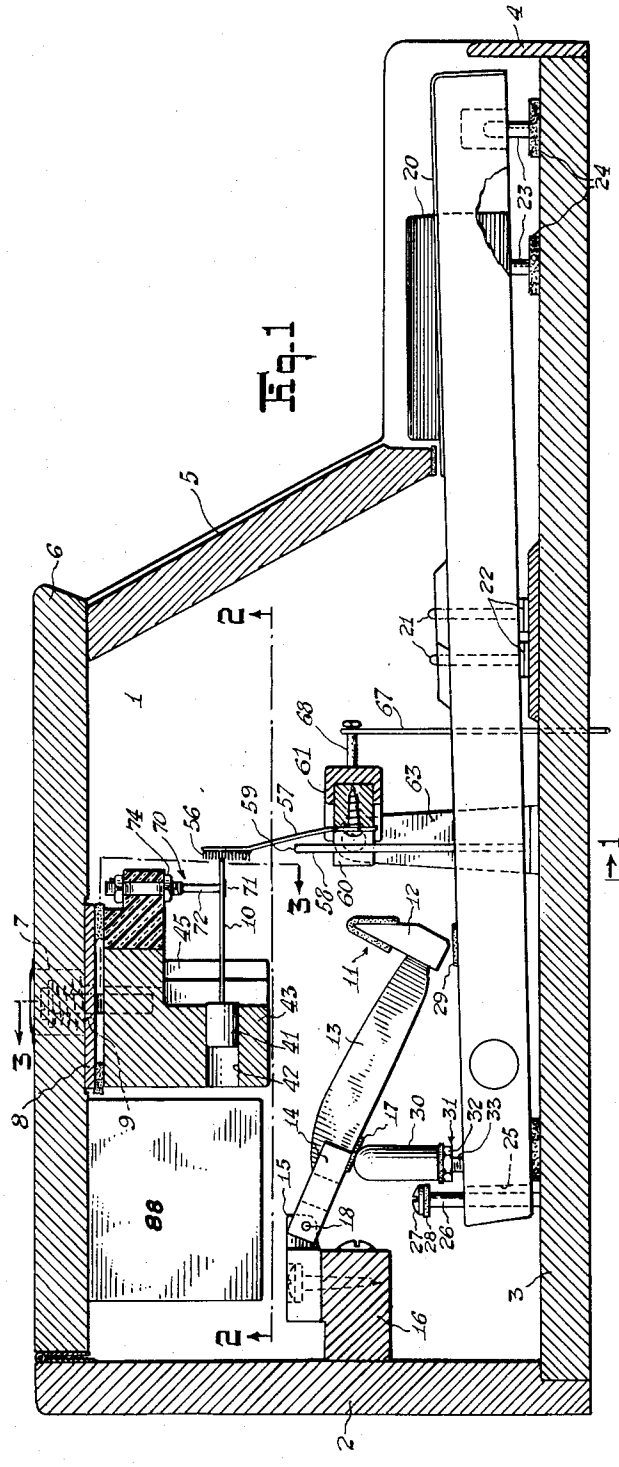


Fig. 1

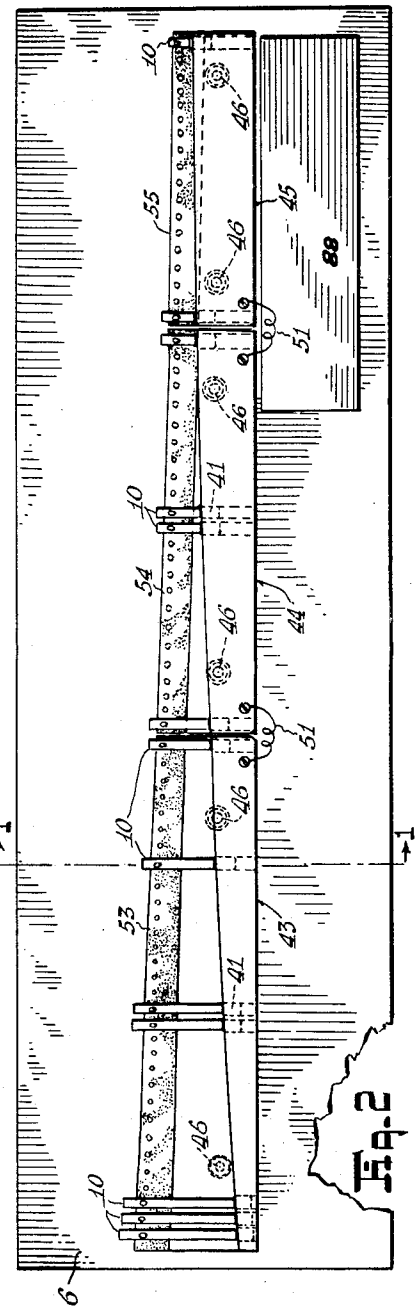


Fig. 2

INVENTOR
Benjamin F. Miessner
BY Charles T. Jacobs
Atty.

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TUNED-VIBRATOR MUSICAL INSTRUMENT

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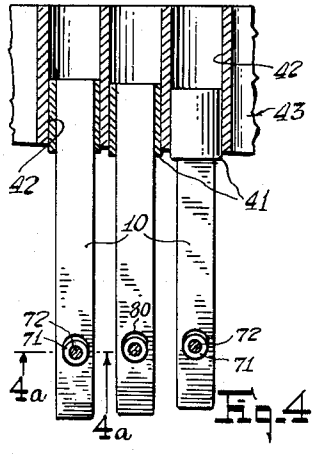


Fig. 4

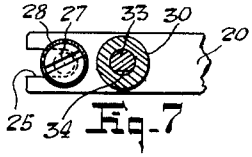


Fig. 7

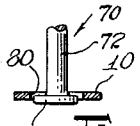


Fig. 4a

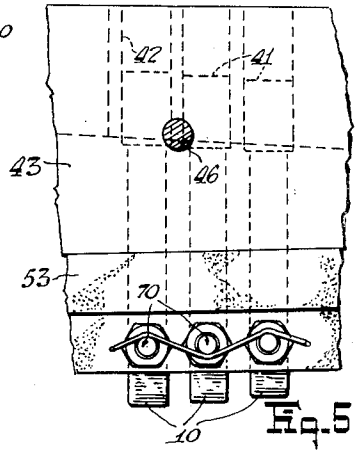


Fig. 5

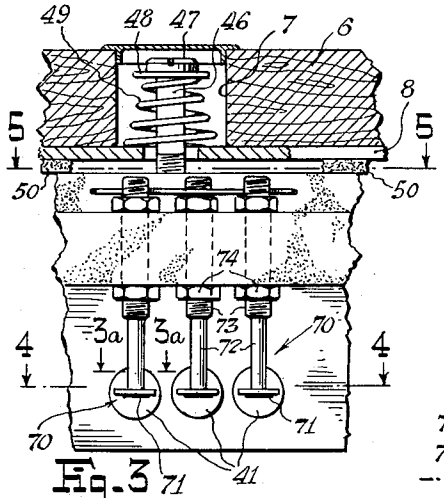


Fig. 3

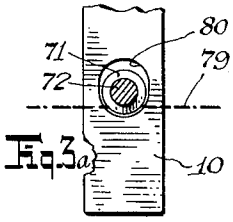


Fig. 3a

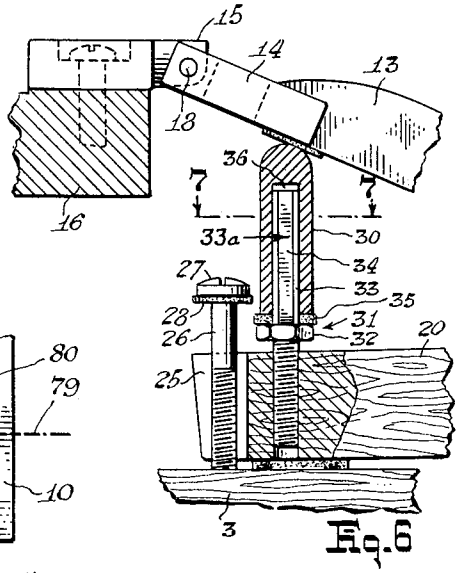


Fig. 6

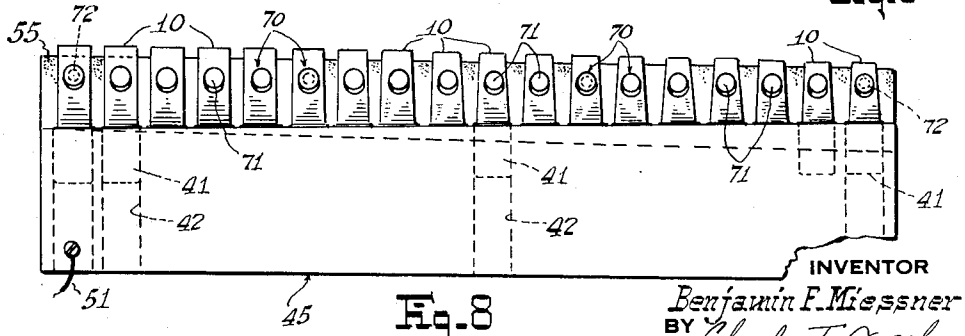


Fig. 8

INVENTOR

Benjamin F. Miessner

BY Charles T. Jacobs

Atty.

United States Patent Office 2,994,239 Patented Aug. 1, 1961

2,994,239

TUNED-VIBRATOR MUSICAL INSTRUMENT

Benjamin F. Miessner, Harding Township, Morris County, N.J., assignor, by mesne assignments, to The Wurlitzer Company, Chicago, Ill., a corporation of Ohio

Original application Feb. 1, 1955, Ser. No. 485,471. Divided and this application May 22, 1957, Ser. No. 660,787

6 Claims. (Cl. 84—1.04)

This invention relates to musical instruments of the type wherein tuned vibrators are impulsively excited into vibration, from which vibrations the output tones of the instrument are translated. The particular instrument illustrated is arranged so that the vibrations of the vibrators, which are fixed-free reeds, are first translated into electric oscillations from which the output tones are in turn translated, but in certain of its aspects my invention is not so limited.

In various United States patents heretofore issued to me, including No. 2,767,608 issued October 23, 1956, I have disclosed simplified vibrator-exciting actions of the percussive variety, wherein for each note a respective hammer is key-propelled to strike the respective vibrator, from which it thereupon rebounds, and wherein a re-rebound of the hammer from its propelling means, with an attendant re-striking of the vibrator, is precluded in one or another simple manner. The present invention comprises an alternative and likewise especially simple vibrator-exciting action achieving these results.

In previous devices I have disclosed, for an instrument employing a progression of tuned fixed-free reeds extending from suitable base means, an arrangement of the base means and reeds which minimizes the unwanted transfer of vibratory energy from an excited reed to one or more of the other reeds of the instrument. The present invention comprises an arrangement of the base means and reeds which still further minimizes such transfer of energy.

It is an object of my invention to provide a simple vibrator-exciting action in which the re-rebound of the hammer to re-strike the vibrator is precluded in an effective and novel manner.

It is an object to provide a generally improved and simplified vibrator-exciting action.

It is an object of the invention to provide an improved arrangement of base means and reeds for minimizing the transfer of vibratory energy from an excited reed.

It is a general object to provide an improved tuned-vibrator musical instrument, and in particular an improved such instrument of the piano type.

Other and allied objects will more fully appear from the following description and the appended claims.

In the description of the invention hereinafter set forth reference is had to the accompanying drawings, in which

FIGURE 1 is a vertical sectional view of an electronic piano embodying my invention (line **1**—**1** of FIGURE 2) indicating the plane along which FIGURE 1 is taken;

FIGURE 2 is a horizontal view taken looking upwardly toward the plane indicated by the line **2**—**2** of FIGURE 1 (or a vertical view seen when looking rearwardly toward the cover **6** of the instrument when the cover is in raised position) and, for simplicity, showing only a few of the reeds **10**;

FIGURE 3 is an enlarged vertical view, in section, taken along the line **3**—**3** of FIGURE 1;

FIGURE 3*a* is an enlarged fragmentary showing of a portion of FIGURE 4;

FIGURE 4 is a horizontal sectional view taken along the line **4**—**4** of FIGURE 3;

FIGURE 4*a* is an enlarged sectional view taken along the line **4***a*—**4***a* of FIGURE 4;

FIGURE 5 is a horizontal sectional view taken along line **5**—**5** of FIGURE 3;

FIGURE 6 is an enlarged fragmentary view, partly in section, of a portion of FIGURE 1;

FIGURE 7 is a horizontal sectional view taken along line **7**—**7** of FIGURE 6;

FIGURE 8 is an enlarged view of a righthand portion of FIGURE 2.

The drawings illustrate a 73-note instrument, but it will be understood that this is by way of illustration only.

In FIGURE 1 the elements **1**, **2**, **3** and **4** respectively represent righthand end, back, bottom and front portions of the cabinet for the instrument, these portions together with the lefthand end portion (not shown) being for example permanently secured together. A removable sloping fall board **5** may extend between the two end portions, while a cover **6** may be hinged at its rear to the top of the back portion **2**. The reeds and pick-ups may be carried by the bottom of the cover **6**, the hammers may be supported by the back portion **2**, and the hammer-actuating keys may be supported on the bottom portion **3**.

The reeds appear as **10**; their mounting, the translation of their vibrations, and related matters are dealt with below. The excitation of each reed is by a respective hammer **11** positioned therebelow, the head **12** of the hammer being propellable upwardly to strike the reed (typically, at approximately the mid-reed nodal point for the third partial vibration of the reed). The hammer head **12** may consist of a chisel-shaped block of wood, preferably covered with felt, or sponge rubber, of progressively greater thickness the lower the frequency of the associated reed. The head **12** is affixed to the forward extremity of a shank **13**, which is preferably of rectangular cross-section with the major dimension of that section vertically disposed. The rear extremity of the shank **13** is in turn secured in the butt **14**, which is pivoted at **18** to flange **15**. All of the flanges **15** are secured on top of a transverse rail **16** fixed to and extending forwardly from the cabinet back **2**.

It may be mentioned that the material of the covering of the hammer head may desirably be characterized by some viscosity, to aid in the damping of upper partials of the reed vibration during the short period of hammer-head contact with reed.

Each hammer is propelled to strike the respective reed by a respective key **20**, acting through a respective controlled rate coupling member **30**. The keys **20** may be pivoted about conventional pins **21**, each key resting on a stack **22** of washers surrounding its respective pin, and may be guided by conventional front guide pins **23** each surrounded by a conventional stack **24** of washers forming a front-end downstop. The rear end of each key is bifurcated by a vertical slot **25** (see FIGURE 9), which freely embraces a respective post **26** screwed into the cabinet bottom **3** and having an enlarged head **27** immediately under which may be provided a thin slightly viscous and elastic washer **28**; the head **27** and washer **28** form an upstop for the rear end of the respective key. The relative adjustments of this rear-end upstop **27**—**28** (effected by rotation of post **26**) and of the front-end downstop (effected by choice of washer thicknesses) are such that when the key is operated the primarily effective stop is the rear-end upstop **27**—**28**—the front-end downstop being a secondary one whose function is to limit deformation of the key which may result from front-end finger pressure continued after the rear-end upstop has acted.

Near its rear extremity each key carries a respective

capstan member 31 screwed into the key (fully seen in FIGURE 6). A little above the key top this member may have the enlarged hex portion 32 engageable by a wrench for vertical adjustment of the capstan member 31. From the hex portion 32 upwardly the capstan member 31 may consist of a rod 33 preferably quite smoothly cylindrical excepting for a longitudinal flat 34 several thousandths of an inch wide (shown in exaggerated width in FIGURE 6).

The respective controlled rate coupling member 30 may comprise a vertically disposed cylinder 30 having, upwardly from its bottom, a circular central bore closely fitting about the rod 33 (excepting for the flat 34 of the latter) but slidable therealong (which action may be aided by a light film of silicone grease on the rod), the upper end of the member 30 being solid and exteriorly rounded into substantially hemispherical configuration. Normally the lower extremity of the cylinder 30 rests on the capstan hex portion 32, through the intermediary of a quite thin slightly viscous and elastic washer 35—and when the cylinder 30 so rests the air chamber 36, formed between the bore of the cylinder and rod 33 at the top of the latter, may be of quite small vertical dimension. Normally the upper end of each coupling member 30 rests the forward portion of the respective hammer butt 14, if desired through the intedmediary of a quite thin layer 17 of slightly viscous and elastic material secured to the bottom of the hammer butt. When the respective hammer butt so rests the lower extremity of the respective hammer head 12 is preferably slightly spaced above a felt pad 29 secured therebelow on the top of the respective key 20.

Operation of the key 20 (i.e., depression of its forward extremity by the finger), if carried out extremely slowly, will of course raise the capstan member 31 and coupling member 30 without disturbance of the normal interrelationship between the latter members, and will swing the hammer butt upwardly about its pivot without any breaking of the contact of the butt with the coupling member. Preferably the components are so geometrically interrelated that this raising will continue to, but be stopped (by the upstop 27—28) at, a position of the hammer head slightly spaced from the bottom of the respective reed 10. No impact of hammer head with reed will occur—just as there occurs in the conventional piano no hammer-string impact when the key is extremely slowly operated. When, however, the key 20 is operated with any substantial velocity, its own sudden stoppage by the upstop 27—28 will not be accompanied by stoppage of either the coupling member 30 or the hammer 11. The hammer will continue under its own momentum, and with negligible change in velocity, to strike and rebound downwardly from the reed. Correspondingly the coupling member 30 will continue upwardly under its own momentum—but in the case of this member there is a substantial and steady loss of velocity as the energy is dissipated at a slow rate, since this coupling-member movement can only occur with an enlargement of the air chamber 36, which can only occur with a flow of air thereinto along the narrow passage 33*a* formed between the bore of the coupling member 30 and the flat 34, which in turn involves substantial energy dissipation through air friction.

Assuming the key remains operated and the capstan member 31 thus in an elevated position, then in the relatively high-velocity rebound of the hammer from the reed its downwardly moving butt 14 will quickly come into impact (through 17 if employed) against the still-rising but now relatively low-velocity coupling member 30. I have found it desirable to make the mass of the coupling member several times the effective mass of the hammer (i.e., the hammer mass as seen at the region of contact between hammer and coupling member). If this be done, the conditions at the time of impact will be such that at the instant after impact the hammer velocity will be very small, while the coupling member will possess most of the kinetic energy previously in the rebounding hammer and will itself be in downward motion toward its normal relationship to the capstan member 31—a motion which involves the diminution of the air chamber 36, which can only occur with a flow of air therefrom along the narrow passageway formed as abovementioned between the bore of the coupling member and flat 34, which in turn involves substantial energy dissipation. Thus although the coupling member while the key remains operated is in a region where it will be struck by the rebounding hammer, a re-rebound of the hammer from it to re-strike the reed—which would occur with all higher-velocity key operations in a conventional system of this general no-escapement type—is precluded by the transfer of the rebounding hammer's kinetic energy to the coupling member and the harmless dissipation from the coupling member of that energy.

It will be understood that a function of the early enlargement of the air chamber 36 is to prepare it for its later diminution and that a function of the energy dissipation during that enlargement is the rapid deceleration of the upwardly moving coupling member, while the function of the energy dissipation in the later air-chamber diminution is the ultimate one (of precluding hammer rebound) just outlined.

In a preferred embodiment of the vibrator-exciting action above outlined I minimize incidental compliances which at the time of impact of the rebounding hammer against the coupling member might yield and thereby divert from the coupling member some of the kinetic energy which desirably is transferred from hammer to it for harmless dissipation as outlined above. Thus I prefer to avoid the use of felt or similar bushings at the pivoting point 18 of butt 14 to flange 15, and to use instead a relatively large-diameter brass pivoting pin; I prefer to use the vertically stiff hammer stem described above; I prefer to minimize the compliance of (or even to omit altogether) the thin washer 35 under the coupling cylinder, and likewise as to the layer 17 above that member (on the bottom of the hammer butt); I prefer to omit yieldable elements from the washer stacks 22 about the pivots 21; and I prefer to use a stiff material for the keys 20 themselves.

In certain aspects the vibrator-exciting action just outlined has some similarities to those described in U.S. Patent No. 2,767,608 issued to me October 23, 1956, and in my co-pending application Serial No. 376,543, filed August 26, 1953 now Patent No. 2,813,447 (which is a continuation-in-part of a prior application Serial No. 292,096, filed June 6, 1952 and since abandoned), but there are several distinctions of importance.

Attention may now be directed to the mounting of the reeds 10, the translation of their vibrations, etc.

The reeds, being of the fixed-free variety, are of course supported in cantilever. The base of each reed is preferably surrounded by a plug 41 of deformable material, and this plug is axially force-fitted into a horizontal hole 42 in an appropriate base member so that the reed effectively extends horizontally from the base member—the base member appearing in section in FIGURE 1 being 43. This structure and method of mounting each reed to a base—whose advantages comprise exceptionally rigid, dissipationless and determinate basing of each reed—are known.

The base member 43 does not support all the reeds of the instrument. For an instrument of this general character, the subdivision of the total base means into a plurality of individual base members each supporting a respective series or group of sequentially tuned reeds is so carried out that each individual base member has a lowest natural frequency of vibration higher than the fundamental frequency of any reed extending therefrom.

In accordance with the present invention a further limitation is observed: that the fundamental frequency of any (in effect, of the highest-frequency) reed secured to any base member shall be lower than the second-partial fre-

quency of any other (in effect, of the lowest-frequency) reed secured to that base member. I have found this limitation important to avoid the possibility that the fundamental-frequency energy of a reed be dissipated by transfer of that energy to second-partial-frequency vibration of another reed secured to the same base member. Since the ratio of second-partial frequency to fundamental frequency in a normal reed without special shaping, aperturing or the like is 6.27, and since even with such practises it tends to remain at least 6.0, this specification is readily met for example by limiting the fundamental-frequency ratio between highest- and lowest-frequency reeds secured to any one base member to less than 6.0—or, in the tempered scale, to some 31 progressively tuned reeds.

Accordingly in the drawings it will be seen that the base member **43** carries the thirty-one lowest-frequency reeds, the base member **44** carries the twenty-four mid-frequency reeds, and the base member **45** carries the eighteen highest-frequency reeds—it being understood that each base member individually obeys the specification set forth in the next-to-last preceding paragraph.

All three base members are indivdually vibrationally insulated to some extent from the cover **6** by which they are supported and, since they may be devoid of any vibrational intercoupling other than through the cover, they may accordingly be considered as vibrationally insulated from each other to a substantial extent. In connection with their mounting, there is secured to the bottom of the cover **6** a transverse metal plate **8** above the positions to be occupied by the base members. Extending upwardly from each base member through respective oversize holes **9** in the plate **8** and into still larger holes **7** in the cover are a pair of studs **46** each screwed into the base member, one near each end of the latter. As best seen in FIGURE 3, each stud terminates in an enlarged head **47**, underneath which may be a metal washer **48**. About each stud, between the washer and plate **8**, there is disposed a conically spiralled compression spring **49**. One half of the weight of each base member appears at a respective spring **49**, as a compressing force exerted thereon through the respective washer **48**, each pair of these springs thus providing the mounting of a respective one of the base members.

The studs **46** are so located in the front-and-back dimension that the base members will have limited tendencies to rock either forwardly or rearwardly, and such tendencies are in any event restrained by strips **50** of sponge rubber or the like placed between the base members and plate **8** near the front and the back edges of the latter (each base member being in effect "floated" by the two respective springs **49** and the sponge rubber strips **50** just mentioned). There is, however, ample opportunity for sufficient rocking of each base member in response to forces applied thereto so that each reed is to some extent vibrationally coupled to all other reeds on the same base member—thus simulating the coupling which exists in the conventional piano between the strings of different notes. If desired, this effect may be carried further by deliberately introducing a modest amount (though it should not be too large) of coupling between the three base members, over and above that which occurs through their mounting to the single cover.

Each of the base members **43**, **44** and **45** may comprise a main metal portion, for example of relatively hard aluminum, and a portion of insulating material appended to the main portion. The cross-section of the metal portion of the low-frequency base member **43** may be of the shape of an inverted L whose horizontal leg is forwardly directed, is of appreciable and constant vertical dimension, and is of length or forward extent varying from a maximum at the lefthand extremity, to a moderate value at the righthand extremity, of the member **43**—and whose vertical leg is of constant height and of thickness varying from a minimum at the lefthand extremity, to a substantial value at the righthand extremity, of the

member **43**. The cross-section of the metal portion of the base member **44** may likewise be of the shape of an inverted L, and at the lefthand extremity of the base member **44** the dimensions of the legs of the L may be similar to those found at the righthand extremity of member **43**; proceeding rightwardly, the length of the horizontal leg may continue to diminish, while the thickness of the vertical leg may continue to increase, for example so that at the righthand extremity of the base member **44** the cross-section of the metal portion has become a simple thick I. At the lefthand extremity of the base member **45** its metal portion may have the cross-section of a simple thick I, for example similar to the cross-section of the righthand extremity of member **44**; proceeding rightwardly, the upper portion may be cut away in front to a small and progressive degree, so that at its righthand extremity the metal portion of the base member **45** may have a cross-section of the shape of an upright L (as indicated by the solid and dotted lines **45'** in FIGURE 1).

It is in the vertical legs of the base members that the reeds **10** are secured (through plugs **41** as above described) and from which they extend forwardly. It will of course be understood that with a constant width and thickness—which I prefer to employ for at least the reeds extending from base members **43** and **44**—then for the required progressive tuning the reed lengths will decrease progressively from a maximum at the lefthand extremity of base member **43** to a relatively short length at the righthand extremity of base member **44**. I prefer to maintain the longitudinal mid-points (more precisely, the mid-reeds nodal points for third partial vibration) of all the reeds in a straight alignment transverse of the instrument—this being so that the hammers, which I prefer to have strike the reeds in each instance at this position, may be arranged in a straight transverse line—and I arrange the front surfaces of the vertical legs of base members **43** and **44** in a gradual curve appropriate to that maintenance. At the same time the rear surfaces of those legs may lie in a transverse vertical plane—which is permitted by the thickness specifications set forth in the preceding paragraph.

The progressive decrease of reed length (and with it the curving of the front surface of the vertical leg of the supporting base member) may be continued throughout the highest-frequency group of reeds (and their supporting base member **45**) as a sole way of accomplishing the required progressive tuning throughout this group. Because of the relatively short reed-length dimension already reached at the righthand extremity of base member **44**, however, I prefer to minimize the further reduction of reed length throughout that highest-frequency group—supplementing the effect of a small length reduction, in achieving the required progressive increase in frequency, by making the sides of the reeds oblique and the free ends thus narrower in progressively increasing degree toward the righthand extremity of the base member **45**, as seen in FIGURE 8. A further expedient which may be resorted to, in minimizing the reduction of reed length throughout this highest-frequency group, is of course a progressive increase in the thickness of the reeds.

The insulating portions of the base members are designated as **53**, **54** and **55**, respectively; each of them may extend forwardly from the upper forward surface of the respective metal base-member portion. (Each of **53** and **54** may form a forward projection of the horizontal leg of the respective metal portion of **43** or **44**, and **55** may form a forward projection from the cut-away upper part of **45**.) In turn the forward part of each of the insulating portions **53**, **54** and **55** may conveniently be cut away at the top (as seen in FIGURE 1) to reduce somewhat the forward-part vertical thickness. It is in this forward part of the base-member insulating portions that the pick-ups are mounted.

Tone-terminating dampers may be provided for the respective reeds (optionally excepting the very highest-

frequency ones). The dampers proper, one of which may be seen in FIGURE 1 and which are designated **56**, may each consist of a small pad of relatively soft material, preferably such as mohair which presents an active surface of generally parallel and closely spaced outwardly extending hairs. Each damper **56** may be secured on the rear upper surface of a respective generally vertical spring **57**, of which the lower portion is secured to a rail **60** referred to below. Normally each damper is lightly biased by its associated spring **57** into contact of its active surface with the free (forward) end of a respective reed **10**. When in this relationship to that reed it will effectively suppress any significant vibration of the reed—and if brought into that relationship to the reed while the reed is vibrating it will effectively and promptly terminate that vibration.

When there is operated the key **20** associated with a reed against which a respective damper **56** is biased, for excitation of that reed, it is of course necesary that the damper be removed from contact with the reed. To accomplish this each such key may be provided, somewhat behind its pivot **21**, with an upstanding heavy-wire arm **58** extending to a position closely spaced behind the normal position of the mid-portion of the respective damper spring **57**, and there folded over into a short horizontal portion **59**. When the key is operated the arm portion **59** will be rocked diagonally upwardly and forwardly, and in this movement will impinge against and move forwardly the respective damper spring **57**, thus placing the respective damper **56** out of contact with the respective reed—a condition which normally will be maintained until release of the key, whereupon the damper will return to contact with the reed and will terminate its vibration.

To provide the conventional "loud pedal" action all the dampers may collectively be removed from contact with their respective reeds. To this end the rail **60**—whose rear surface may be a gradual curve conforming to the similar curve formed by the free ends of the reeds—may have a straight forward edge which in turn is inset into a U-cross-section channel member **61**. The assembly **60—61** at its extremities may be pivoted to suitable standards, the righthand one of which appears in FIGURE 1 as **63**.

The assembly **60—61** may be biased about its pivots (counterclockwise as seen in FIGURE 1) to a predetermined angular position (typically that shown in FIGURE 1) by suitable biasing and stop means (not shown). The assembly **60—61** may be rocked against its bias (i.e., clockwise as seen in FIGURE 1)—thus removing all dampers collectively from contact with their associated reeds—by downward longitudinal movement of a rod **67** which at its upper extremity is loosely secured to an arm **68** extending forwardly from the channel member **61**. Such downward movement of the rod **67** may be effected in any convenient manner, most typically by a pedal (not shown) with which its lower extremity may be suitably associated.

I have found it highly desirable in the production of the most pianistic tones from impulsively excited fixed-free reeds—whose upper-partial vibrations (i.e., all above the first, or fundamental) are well known to be normally inharmonically related to the fundamental—to observe several specifications:

A. To utilize means in the mechanical system which if formed by the exciting means and the vibrator to substantially eliminate from the translated oscillations an inharmonic component corresponding to one of the lower-numbered of the upper partials at which the reed tends to vibrate—preferably (if the preference under B below be followed) the third partial;

B. To arrange the mechanico-electrical system which is formed by the pick-up device and a portion of the vibrator so that in it is performed the function of substantially eliminating from the translated oscillations an inharmonic component corresponding to one of the lower-numbered of the upper partials at which the reed tends to vibrate—preferably the second partial;

C. To arrange the mechanico-electrical system abovementioned so that by it is performed the function of introducing, into the electric oscillations which it translates from the reed vibrations, a series of upper partials harmonically related to the fundamental—preferably a series which diminishes in composite magnitude (relative to the magnitude of the fundamental) as the vibration of the reed dies away after its impulse excitation; and

D. To arrange the mechanico-electrical system abovementioned so that the greater deformations of the reed attendant on high-amplitude vibration, though involving quite inharmonic partials, are utilized to enhance the generation of the abovementioned harmonically related upper partials, as well as to enhance the translation of the fundamental, in the electric oscillations during the very initial instants following the impulse excitation of the reed.

Specifications A and B, taken together and utilized with respect to the second and third reed-vibration partials, serve the highly important function of rendering harmless the significant ones of the inharmonic (i.e., all upper) partials at which the reed tends to vibrate—since partials above the third are normally sufficiently weak so that their translation has a negligible deleterious effect on output tone. Stated in other words, they cause the reed—though actually still excited in the simple impulsive manner required for a pianistic type of tone—to approximate in its effect a vibrator whose vibration is free of partial development (i.e., whose vibration occurs only at its fundamental frequency).

The function just mentioned—highly important since substantial inharmonic components, especially continuing (as distinguished from transient) ones, are intolerable in tones intended to be pianistic—would resulft, taken alone, in an unusably dull tone, quite unpianistic because it would lack the rich development of upper partials harmonically related to the fundamental which is characteristic of the piano. It is to cure this lack, by creating just such a rich development of harmonic upper partials, that specification C is combined with A and B.

It will be convenient first to describe the pick-up means and how the structure meets specifications A, B, and C, and then to bring out the importance of specification D and how the structure meets it.

Specification C may be met by arranging the pick-up means so that it is principally influenced by an edge portion of the reed, which preferably will most fully influence it twice in each cycle of vibration at substantial amplitude—it being preferably so arranged that the instance of greatest influence, through bicyclic, are never separated by precisely 180 degrees (thus avoiding pure double-frequency translation). Reference being had to FIGURES 3, 3*a*, 4 and 4*a*, there will be seen for each reed a pick-up means **70**. Each such pick-up means may comprise a threaded portion **73** conveniently passing vertically through the forward part of the associated base-member insulating portion (e.g., through the forward part of **53**) and there anchored by means of two nuts **74** threaded on the portion **73** and tightened against the base-member insulating portion, one on top and the other on the bottom. Each pick-up means may further comprise a rod portion **72** preferably of reduced diameter forming a downward projection of the threaded portion, and may finally comprise an active pick-up portion **71**—typically in the form of an abrupt enlargement of the rod portion at its end into a thin transverse end plate (for example, of thickness generally similar to that of the associated reed). Seen in plan view of reed and end plate (e.g., in FIGURE 3*a*), the end plate **71** is closely spaced from an edge portion of the reed. Vertically, the pick-up means may be so adjusted (by nuts **74**) that the end plate **71** is very nearly at the level of the reed when the

latter is in its at-rest position, for example (see FIGURE 3) so that its central plane approximately coincides with the plane of the bottom of the at-rest reed.

It is of course desirable that the natural frequency of each pick-up device be higher than the fundamental frequency of the highest-frequency reed of the instrument. It is further desirable that the material be soft enough to permit accurate placement of the end plate **71** horizontally, relative to the reed, by slight bendings of the rod portion **72**, preferably effected with the aid of an appropriate bending tool.

It will be understood (i) that when the reed moves upwardly the capacity between it and the end plate **71** will progressively reduce; that as the reed moves downwardly from an upward excursion that capicity will progressively increase, reaching its original value when the reed reaches its at-rest position; that as the reed continues to move downwardly that capacity will at the very first still further increase somewhat, to a maximum when the reed and end plate are in alignment (i.e., when the central planes of the two coincide), and will then progressively decrease; and that as the reed moves upwardly from a downward excursion that capacity will progressively increase, reaching its abovementioned maximum when the central planes of reed and end plate coincide, and will then decrease to reach its somewhat smaller original value when the reed reaches its at-rest position—this analysis of course assuming that the reed movement is of sufficient amplitude so that in its downward excursion it proceeds beyond a position of alignment with the end plate **71**. It will further be understood (ii) that the higher the amplitude of reed movement, or vibration, and thus the greater its velocity in passing its positions of maximum capacity abovementioned, then in the waveform of the capacity variations the greater will be the steepness of the approaches to and recessions from maximum capacity. It will still further be understood (iii) that if the reed be vibrating at very high amplitude the intra-cyclic instants of maximum capacity—both occurring in the downward excursion half-cycle—will be separated by almost (but never fully) 180 degrees; that as the amplitude reduces that separation will reduce; and that when the reducing amplitude has reached a value only sufficient (at the peak of the downward excursion) to align the reed with the end plate that separation will have reached zero—after which there will be in each cycle only one instant of maximum capacity.

As will hereinafter more fully appear, with this type of pick-up means the translated oscillations are a function of the variations of the capacity between the reed and the pick-up means. Also, as is well understood, an intra-cyclic departure from pure sinusoidal character, if repeated from cycle to cycle (subject to no more than minute amplitude shifts from one cycle to the next) gives rise to the generation of partials which are limited to integral multiples in frequency, or true harmonics, of the fundamental. Accordingly it is the action described in (i) above (in fully understanding which (ii) and (iii) above are helpful) which meets the basic portion of specification C—that the pick-up means, in its translating action, introduce into the translated oscillations a series of upper partials harmonically related to the fundamental. Further, it is the actions described in (ii) and (iii) above which meet the supplementary portion of specification C—that the series of harmonic upper partials diminish in composite magnitude as the vibration of the reed dies away ("magnitude" being used in the sense of amplitude relative to the amplitude of the fundamental).

In the structure specifically illustrated in the drawings the edge portion of the reed which principally influences the active portion of the pick-up (i.e., end plate **71**) is an internal edge portion, created for example by piercing the reed with a somewhat elongated hole **80**. The outer portion (i.e., the portion toward the free extremity of the reed) of the periphery of the hole may, for example and as illustrated in FIGURE 3*a*, be of semicircular formation, and it is from this portion that the active pick-up portion or end plate **71**—which in this case may for example be circular—is closely spaced. In FIGURE 3*a* the dash-dot line **79** may be taken as very approximately illustrating the region, longitudinally of the reed, of average influence of the reed on the pick-up. To meet specification B this region, as to each reed, may most desirably be at the longitudinal position of the node for the second partial of the reed vibration. In the case of an unpierced reed of uniform cross-section this node falls at a position removed from the base of theh reed by approximately 78% (and from the free end of the reed by approximately 22% of the reed length—and the piercing of the reed appears to make no first-order change of this position, so that a positioning of the hole to bring the line of average influence of reed on pick-up at a position removed from the base of the reed by approximately 78% of the reed length represents a close compliance with specification B.

It is to meet specification A that the hammers have been called for above preferably to strike the reed at the mid-reed node for the third-partial reed vibration—which node in the case of an unpierced and uniform cross-section reed falls almost precisely at the longitudinal mid-point of the reed, and is not substantially altered by the piercing.

It will of course be understood that the manner in which the mid-reed nodal striking of the reed meets specification A—i.e., in which it substantially eliminates from the translated oscillations an inharmonic component corresponding to the third partial at which the reed tends to vibrate—is by substantially eliminating the presence of that partial in the reed vibrations, on a selective basis. The difference between this and each of the other means of meeting specification A above referred to will be apparent.

When a fixed-free reed is vibrated at high amplitude—which is the case initially after strong excitation—at a plurality of its partial frequencies the deformation attendant on the upper-partial vibration components produces an effective shortening of the reed; this might be termed a temporary or dynamic shortening. Considering the first-partial (or fundamental) vibration, which is the one of course relied on in the abovementioned functioning of the structure, this dynamic shortening will temporarily increase the spacing of the locus of the vibrating-reed extremity from any pick-up located just beyond that extremity. Since the efficiency of translation is a sharp inverse function of such spacing, there takes place during the initial high-amplitude vibration a very noticeable reduction of translation efficiency. Thus, with a pick-up located just beyond the free extremity of the reed, there can and does occur an actually observable increase of amplitude of the translated oscillations during the early instants after reed excitation, as the dynamic deformation subsides and the translation efficiency therefore increases.

This time is one when, in a normal piano, a very noticeable decrement of the output sound occurs; indeed, an especially high initial decrement—i.e., decrement during the first few instants of a tone—is a strong distinguishing feature of piano tone.

By arranging the pick-up means so that the edge portion of the reed which most actively influences it is a longitudinally intermediate portion, or portion other than the free extremity of the reed—for example, by arranging it so that that edge portion of the reed is a side-edge portion—the disadvantage just discussed is obviated. Thereby a worthwhile improvement in respect of tone-inception characteristics is achieved.

I have found, however, that important still further improvement is possible. It is achieved by arranging the pick-up means so that the locus of the portion of the reed which principally influences it—instead of being brought

further away from it, or left unchanged, by the dynamic shortening of the reed—is by that dynamic shortening brought closer to it. It is for this reason that I have employed, for the portion of the reed which principally influences the pick-up means, an internal edge portion—and have selected for that edge portion the outer (rather than the inner) peripheral portion of the hole **80**. This represents a longitudinally intermediate edge portion specially selected for positive additional advantages.

It will be understood that the effect of this favorable utilization of the dynamic shortening of the reed during the early instants following the excitation of the reed is not only to enhance the translation of the fundamental (thereby increasing the initial decrement, as is desirable), but also then to increase the generation of harmonically related upper partials—since the steepness of the waveform of capacity variation is likewise increased by this utilization. It is so that specification D is met. This is of especial importance since a distinguishing feature of piano tone, over and above the high initial decrement, is a very initial burst of momentarily accentuated harmonic development.

The pick-up means have so far been described without particular limitation as to type—and as to broader aspects none is intended. In a more specific aspect those disclosed are of the capacitative type (though their analogues, magnetic for example, will be readily understood). For the capactitative type, in turn, no limitation as to particular species is intended, as between those operating for example on a D.C., on an amplitude-modulating, or on a frequency-modulating basis—each of which in broad outline is well known in the art and need not here be detailed. With the disclosed pick-up means, whatever be the species used, the associated electrical and electronic circuitry (including for example the associated pre-amplifier) may be formed as a compact unit **88** which, if desired and as indicated in FIGURES 1 and 2, may be physically disposed below the cover **6** behind the base members **45** and **44** at the treble extremity of the instrument.

This application is a division of my co-epnding application Serial No. 485,471, filed February 1, 1955, and now abandoned, which contains claims to certain of the subject matter herein disclosed.

While I have disclosed my invention in terms of a particular embodiment thereof, it will be understood that unnecessary limitations are not thereby intended, since by the disclosure various modifications will be suggested to those skilled in the art. Such modifications will not necessarily constitute a departure from the scope of the invention, which I undertake to express in the appended claims.

I claim:

1. A percussion-type musical instrument comprising base means, a vibrator carried by said base means, a key movably mounted on said base means and adapted to be moved by manual engagement thereof, a hammer movably mounted on said base means for percussive engagement with said vibrator, and a controlled rate energy dissipating coupling member comprising a pair of relatively movable elements interfitting in energy dissipating relation, the first of said elements being mounted on said key and the second thereof being in driving engagement with said hammer, whereby manual movement of said key to a limit position acts through said coupling member to propel said hammer into engagement with said vibrator, said hammer moving out of engagement with said coupling member and the second element moving away from the key relative to the first element, said hammer upon rebounding from said vibrator re-engaging said second element and moving said second element in energy dissipating manner relative to said first element to absorb energy of the rebounding hammer for preventing the hammer from restriking the vibrator.

2. A percussion-type musical instrument as set forth in claim 1 and further comprising friction energy dissipating means disposed between said elements.

3. A precussion-type musical instrument as set forth in claim 2 wherein one of said elements comprises a piston and the other comprises a cylinder providing a dashpot air friction type mechanism.

4. A percussion-type musical instrument as set forth in claim 3 wherein the piston has a flat thereon providing a limited air passage between said piston and said cylinder.

5. A percussion-type musical instrument as set forth in claim 1 wherein said vibrator is mounted at one end and is free at the oppsite end, and further including a damper engagable with the free end of the vibrator and a member on said key engagable with said damper for retracting said damper from engagement with said vibrator upon movement of said key.

6. A percussion-type musical instrument as set forth in claim 1 wherein the vibrator is mounted above the hammer, and the hammer is mounted above the key, said hammer moving upwardly into percussive engagement with said vibrator and being gravitationally returned.

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