July 3, 1962 B. F. MIESSNER 3,041,909

ELECTRONIC PIANO

Filed July 23, 1957 2 Sheets-Sheet 1

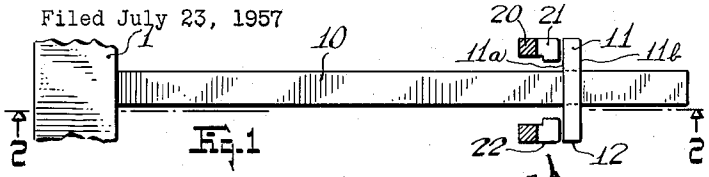


Fig. 1

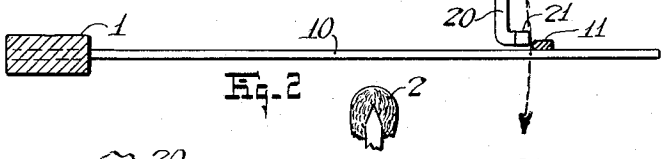


Fig. 2

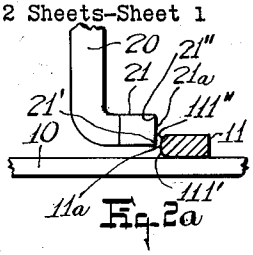


Fig. 2a

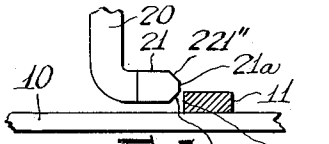


Fig. 3

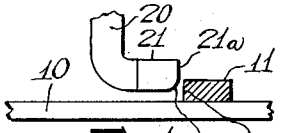


Fig. 4

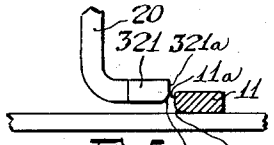


Fig. 5

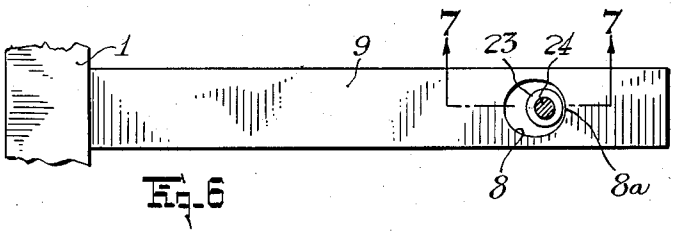


Fig. 6

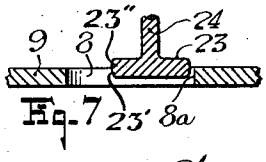


Fig. 7

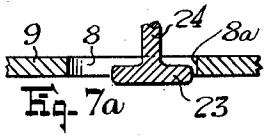


Fig. 7a

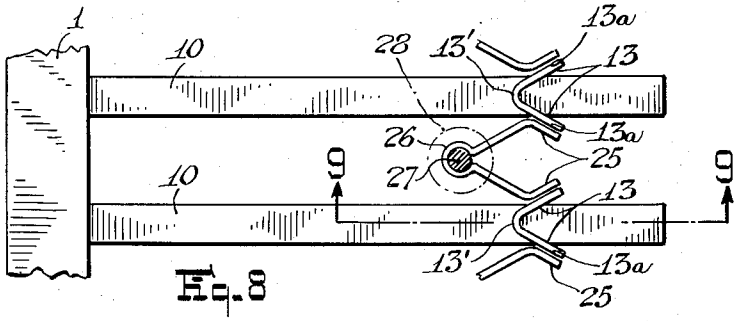


Fig. 8

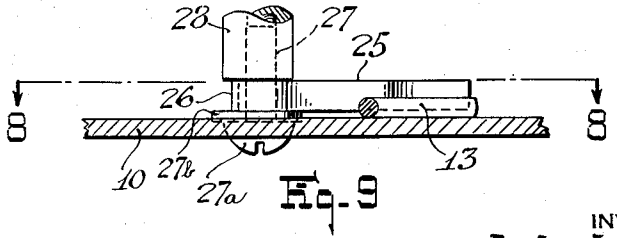


Fig. 9

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ELECTRONIC PIANO

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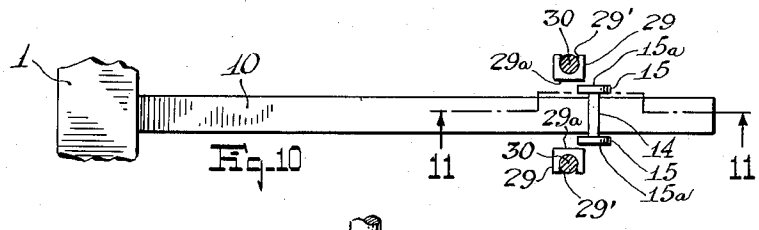


Fig. 10

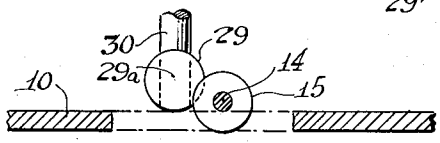


Fig. 11

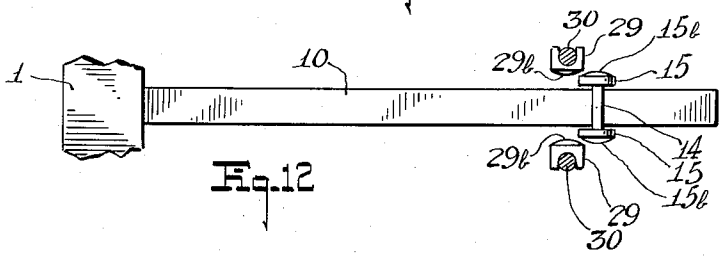


Fig. 12

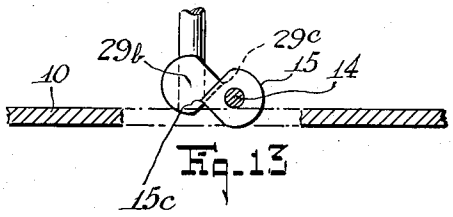


Fig. 13

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United States Patent Office 3,041,909 Patented July 3, 1962

3,041,909

ELECTRONIC PIANO

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Filed July 23, 1957, Ser. No. 673,725
9 Claims. (Cl. 84—1.14)

This invention relates to electronic musical instruments, and more particularly to such instruments for the production of pianistic tones.

It is an object of my invention to achieve an initial decrement in musical tones, produced by electrical translation from the vibrations of impulsively excited fixed-free reeds, which frequently are characterized by slight initial increments or abnormally low decrements.

It is an object generally to improve the initial characteristics of such tones.

It is an object to improve the simulation, by an instrument employing impulsively excited fixed-free reeds electrically translated from, of a conventional piano.

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

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

FIGURES 1 and 2 are respectively plan and vertical cross-sectional views of a reed and associated pick-ups according to my invention in one form;

FIGURE 2*a* is a fractional enlargement of a portion of FIGURE 2;

FIGURES 3, 4 and 5 illustrate a respective three modifications of the structure seen in FIGURE 2*a* in respect of a feature hereinafter dealt with;

FIGURES 6 and 7 are respectively plan and fractional enlarged vertical cross-sectional views of a reed and associated pick-up according to my invention in another form;

FIGURE 7*a* illustrates a readjustment of the portion of the assembly shown in FIGURE 7;

FIGURES 8 and 9 are respectively plan and fractional enlarged vertical cross-sectional views of two reeds and asociated pick-ups according to my invention in still another form;

FIGURES 10 and 11 are respectively plan and fractional enlarged vertical cross-sectional views of a reed and associated pick-ups according to my invention in a further form;

FIGURE 12 is a plan view of a reed and associated pick-ups according to my invention in a still further form; and

FIGURE 13 is an enlarged vertical cross-sectional view illustrating an optional peripheral configuration of active reed portion and pick-up appropriate to the embodiment of either FIGURE 10 or FIGURE 12 (preferably the latter).

Reference being had to FIGURES 1 and 2, there will be seen a metallic fixed-free reed **10** projecting horizontally from any suitable mounting base **1**. The reed may be arranged to be impulsively excited into verical vibration, as by a hammer fractionally shown as **2**, which strikes a reed—for example, at its longitudinal mid-point, which (for a unform-cross-section unweighted reed) is substantially a node for the third vibration partial, thus substanially eliminating any third-partial component from the ensuing vibration of the reed. That vibration will of course be decadent—i.e., will decrease progressively with time following the excitation—but with suitable base arrangements the rate of decay will be suitably low.

Extending laterally from the reed is a metallic projection **11**; this may be provided in any suitable manner, for example by a cross-bar fixed, as by soldering or welding, to the top of the reed. The projection **11** is preferably

so positioned longitudinally of the reed that its inner face or tone generating surface **11***a*—i.e., the surface which faces toward the fixed extremity of the reed—is at the node for the second-partial vibration of the reed. (This node, for an unweighted uniform-cross-section reed, is at a distance approximately $^{78}/_{100}$ of the reed length from the fixed extremity; for a reed weighted by the projection it may shift very slightly dependent on the precise characteristics of the projection, as may also the mid-reed node for the third partial where it is desirable to strike the reed, but such shifts are readily determined by test in any particular case.) It is with the inner face **11***a* of the projection that the pick-up is associated.

The pick-up in FIGURES 1 and 2 appears as **21**, in the form of a flat horizontally arranged stationary electrode, typically somewhat thicker than the reed. It is located in close spaced relation to the vibratory locus or path of motion of the surface **11***a*, and is much more substantially spaced away from the side of the main body of the reed so that it is principally influenced by and responsive to the surface **11***a*. It may be folded over from a downhanging vertical stem **20** fractionally shown in FIGURE 2, this stem being so arranged as itself to have negligible capacity to the projection **11** or any other portion of the reed at any position of the reed within the reed's vibratory range. In the direction of reed vibration, or vertically, the pick-up may be displaced very slightly (as illustrated, upwardly) from the rest position of the reed projection **11**, so that the maximum interception of the pick-up's field by the projection (i.e., the maximum capacity, or exposure, of the reed to the pick-up), as influenced by the vertical motion of the reed, will occur when the reed is very slightly displaced (upwardly) in its fundamental mode from its rest position.

With the illustrated capacitative type of pick-up—which as is now well understood may be connected, as will also be the reed, into a suitable electrical circuit (not shown) operating on a simple D.C. basis, or on an amplitude-modulating high-frequency or a frequency-modulating high-frequency basis—the oscillations translated by the pick-up from the reed vibrations are functions of the capacity between the pick-up and the reed, of which latter the projection **11** is of course considered as forming a portion.

In the rest position of the reed the capacity between it and the pick-up is substantial. In a high-amplitude upward excursion of the reed from its rest position that capacity will at the very first increase somewhat, until the bottom of the projection **11** is level with the bottom of the pick-up **21**; from then until the top of the projection is level with the top of the pick-up the capacity will remain fairly constant at a high value (though with a slight discernible maximum when the projection and pick-up are most fully aligned with each other—i.e., have their horizontal central planes at the same level); thereafter the capacity will progressively decrease to a quite low value dependent on the distance of the upward excursion. As the reed moves downwardly in return from that excursion the capacity will progressively increase to the above-mentioned fairly constant high value, reached when the top of the projection is level with the top of the pick-up and maintained (though again with the discernible slight central maximum) until the bottom of the projection passes below the bottom of the pick-up; thereafter the capacity will reduce somewhat until the reed reaches its original rest position and original capacity to the pick-up. As the reed continues its downward movement the capacity will continue to reduce progressively to reach, when the reed reaches the limit of its downward excursion (one-half cycle later than it reached its limit of upward excursion), a value still lower than reached in the upward excursion. As the reed moves upwardly in return from

its downward excursion the capacity will progressively increase, reaching its original value when the reed reaches its rest position. Thereupon the cycle above described will repeat itself recurrently, subject to the progressive amplitude reduction from cycle to cycle implicit in the decadent nature of the reed's vibration.

From the foregoing analysis it will readily be appreciated that in the translated oscillations there will be reproduced two similarly directed peaks per cycle of fundamental vibration of the reed, and that these peaks will have a separation of almost 180 degrees in the case of high-amplitude vibration. That separation will reduce as the amplitude reduces; when the reducing amplitude has reached a value only sufficient to bring the top of the projection **11** level with the top of the pick-up **21** in the upward excursion, that separation will have reached zero—after which there will be in each fundamental cycle only one peak in the direction in which there formerly were two.

It is well understood that an intra-cyclic departure from pure sinusoidal character, if repeated from cycle to cycle (subject at the most to sufficiently minute shifts from each cycle to the next as an incident of gradual decay of amplitude) gives rise to the generation of partials which are limited to integral multiples in frequency, or true harmonics, of the fundamental. From this it will in turn be understood that the translated oscillations—being functions of the described capacity variations, which at higher amplitudes depart widely from sinusoidal character—will contain a series of upper partials harmonically related to the fundamental, derived from the fundamental vibration through the action of the pick-up. It will at the same time be understood that as the amplitude of vibration decays (and the departure from sinusoidal character gradually reduces) the series of harmonic upper partials in the translated oscillations will diminish in composite magnitude (i.e., amplitude relative to the fundamental component).

The foregoing description of operation has been presented in terms which would be wholly appropriate to the suppositious case wherein the reed vibration occurred at the reed's fundamental mode only. Actually, of course, the impulse excitation results in vibration of the reed at its upper-partial modes as well. But in the described structure the surface **11***a* (to which the pick-up is principally responsive) is essentially free of any vertical vibration component at the frequency of the second partial, as a result of its placement at the node for that partial, while the excitation of the reed at a node for the third partial essentially precludes the presence of any component of that frequency in the vibration; thus components corresponding in frequency to the reed's second and third partials are for practical purposes absent from the translated oscillations. Fourth- and higher-partial components of the vibration are ordinarily rather weak (especially if, as is preferred, a reasonably soft surface be provided for the hammer **2**) and are increasingly more highly damped; the relatively minute and highly damped traces of these components in the translated oscillations are sensed simply as simulating the initial "ring" heard on strong excitations in the lower and middle registers of the conventional piano, and are unobjectionable.

The higher-, and particularly the second-, partial components in the reed vibration, although harmless as first-order contributors to the translated oscillations for reasons just brought out, have another very significant effect. This arises from the deformations which they cause in the reed, relative to the smoothly curved shapes it would successively assume were it vibrating at its fundamental mode only. The effect is that of a temporary, or dynamic, shortening of the reed—i.e., a reduction of the separation of any active point on the reed from the fixed reed extremity—occurring twice in each cycle of the second- (or other higher-) partial vibration. This shortening is of course at a maximum when those components are of highest amplitude, which in turn is of course in the very initial part of the tone—not only because all components are then highest, but additionally because each progressively higher vibration partial is more rapidly damped than the next lower one.

With respect to any active point on the reed the result of this dynamic shortening is that the point's vibratory locus or path of motion, which in the absence of the dynamic shortening would be substantially an arc of a circle (about a center located near the fixed extremity of the reed), remains circular in nature but becomes the space between that circle and a slightly smaller concentric circle. With respect to a transverse line across an active part of the reed—or with respect to a transverse vertical surface such as **11***a* or such as the free end of the reed—the result is that its vibratory locus, which in the absence of the dynamic shortening would be substantially a part of a single cylinder, remains cylindrical in nature but becomes the space between that cylinder and a slightly smaller coaxial cylinder. In neither case has the dynamic shortening moved the outer boundary of the locus, but in each case the inner boundary of the locus has been temporarily moved, by that shortening, toward the fixed extremity of the reed—and obviously the locus as an entirety has been temporarily altered or shifted.

It will be understood that during the period of substantial dynamic shortening, during which the vibratory locus of the point (or transverse line or vertical surface) under consideration occupies the space between two limiting boundaries, that point (or transverse line or vertical surface) is in process of shifting between those boundaries, bicyclically at each of the actually-present higher-partial vibrational frequencies of the reed—each of which is normally randomly related in frequency to the fundamental vibration—in a manner which may be thought of as reciprocating in a direction lengthwise of the reed, and as superimposed in the generally up-and-down cyclic movement of the point (or transverse line or vertical surface) at the fundamental frequency.

With a structure in which a pick-up were located just beyond the free extremity of the reed (or with a structure such as that of FIGURES 1 and 2 but with the pick-up relocated to be in close spaced relation to the outer face **11***b*, instead of the inner face **11***a*, of the projection **11**) the dynamic shortening would temporarily increase the spacing, from the pick-up, of the inner boundary of the vibratory locus of the portion of the reed which principally influenced the pick-up—and would therefore increase the mean spacing, from the pick-up, of that locus as an entirety. Since the efficiency of the translation of oscillations by the pick-up is a sharp inverse function of such spacing, there would take place during the very initial high-amplitude vibration resulting from stronger excitations a noticeable reduction of translation efficiency. Thus with a pick-up located as in either manner above in this paragraph mentioned, there can and does occur a noticeably weakened tone inception, and an actually observable increase of amplitude of the translated oscillations through the earlier instants following that inception, as the dynamic deformation and shortening subside and the translation efficiency therefore increases. There earlier instants are a time 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 earlier instants of a tone—is a strong distinguishing feature of louder piano tones.

By arranging a pick-up so that the edge portion of the reed which most actively influences it is, for example, 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 relative to the reed so that the vibratory locus of

the portion of the reed which principally influences the pick-up, instead of being altered or shifted by the dynamic shortening so that the pick-up is less fully exposed to it (i.e., being caused less fully to intercept the pick-up's field) or of being left unaltered in effective relation to the pick-up, is by that dynamic shortening altered or shifted so as more fully to expose the pick-up to it (i.e., is caused more fully to intercept the pick-up's field). It is for this reason that I have employed, in FIGURES 1 and 2, for the portion of the reed to which the pick-up is principally responsive, the inner face **11***a* of the projection **11**—of which by the dynamic shortening the inner boundary of the vibratory locus is brought closer to the pickup, and the locus as an entirety is altered or shifted so as more fully to expose the pick-up to it (i.e., so as more fully to intercept the pick-up's field).

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 then-occurring translation of the fundamental (to result in an increase of the initial decrement of the fundamental component in the translated oscillations, as is desirable), but also then to temporarily increase the generation, in the translation, of harmonically related upper partials—since the dynamic shortening and closer spacing increase the steepness of the waveform of the capacity variations, of which steepness that generation is a function. This is of especial importance since a distinguishing feature of stronger piano tones, over and above the initial general decrement, is a very initial burst of momentarily accentuated harmonic development.

It will be understood that during the period of substantial dynamic shortening, during which the vibratory locus of the reed portion principally influencing the pick-up occupies the space between two limiting boundaries (e.g., cylinders), that reed portion is in process of shifting, bicyclically at each of its actually-present higher-partial vibrational frequencies, in a manner which may be throught of as reciprocating in a direction lengthwise of the reed. It will also be understood that this bicyclic reciprocating movement of the surface **11***a* at each of the upper-partial vibrational frequencies, which is superimposed on the up-and-down cyclic movement of the surface **11***a* at the fundamental frequency, will not be wholly devoid of influence on the translation. But the lowest-frequency and principal influence occurs at double the second-partial vibrational frequency (which itself is 6.28 times the fundamental, for an unweighted and uniform-cross-section reed), and consists of the introduction, into the translated oscillations at minute intervals (representing the times of transit of the surface **11***a* past the pick-up) occurring twice in every fundamental cycle of substantial vibration of the reed, of a component of that double-the-second-partial vibrational frequency. The ear senses these minute introductions or injections as a weak inharmonic component, of course high in frequency and very highly damped (since the second-partial vibration is itself relatively highly damped, and its double-frequency derivative here under discussion tends to decrease approximately as the square of its amplitude). The net effect is unobjectionable, since it no more than simulates the initial "ring" heard on strong excitations in the lower and middle registers of the conventional piano (resulting from minute longitudinal string vibrations, wrapping-wire characteristics in the case of loaded strings, and the like).

In FIGURE 1 I have illustrated a second pick-up **22**, similar to the pickup **21** and located similarly with respect to the reed **10** and its cross-bar but on the opposite side of the reed from the pick-up **21**—the cross-bar being suitably extended on the second side of the reed, just as on the first, to form a second projection **12**. The provision of the second projection and the second pick-up is not indispensible, but is desirable for the purpose of balancing the structure against undesirable effects which might otherwise occur from unintended components of vibration of the reed in its own plane (which would normally be randomly related in frequency to the fundamental frequency of the intended vertical vibration).

I have above pointed out that it is the very substantial intra-cyclic departure, of the waveform of variations of the exposure (e.g., of the capacity) of reed to pick-up, from pure sinusoidal character which serves to introduce, into the oscillations translated from the fundamental reed vibrations, a series of upper partials harmonically related to that fundamental. I have there also pointed out that it is the substantial repetition of these variations from fundamental cycle to fundamental cycle which insures that only harmonically related upper partials will be so introduced—and have there also recognized that, owing to the decadent nature of the vibration, the repitition necessarily departs from an absolutely rigorous one. With a structure such as that of FIGURES 1 and 2 this departure is, as abovementioned, in respect of the inter-peak spacing between the two similarly directed peaks per fundamental cycle; it is of course also, although this was not specifically mentioned above, in the respect of the width of the peaks—which of course becomes progressively greater as the vibration amplitude reduces. (What has just been said will be recognized as generic, as well, to other structures not taking advantage of, or even suffering an actual disadvantage from, dynamic shortening.) Thus there is on principle an opportunity for the generation, in the translation, of a component or components not harmonically related to the fundamental—and in practise I have found that such a component is sometimes generated.

Specifically I have sometimes observed, superimposed on the early part of a strong tone otherwise of wholly harmonic and generally very acceptable nature, a relatively weak but discernible high-frequency component of pitch which descends progressively over the early part of the tone; it might be very loosely described as a "meow" intruding in that portion, and is of course wholly foreign to good piano-type tone. As a result of painstaking practical research I have discovered that it may be eliminated by a simple technique. This I shall proceed to describe in connection with the manner in which I believe the component to be generated, though it is to be understood that the technique remains a practical solution to the problem, whether or not the theory of the manner of generation is in all respects accurate.

In the description, presented above, of the manner in which the capacity between reed and pick-up varies in each cycle of higher-amplitude reed vibration there will be noted the fact that each of the two similarly directed capacity (and thus oscillation) peaks has a fairly constant, and thus fairly flat, top. The angle formed between the approach side of the oscillation peak and that top, and the angle formed between that top and the recession side of the oscillation peak, are in each instance quite sharp. In an upswing of the reed the sharpness of the former is the result of the bottom mutually-facing angles **111′** and **21′**, of projection and pick-up respectively, both being assumed to be sharp, and the sharpness of the latter is the result of the top mutually-facing angles **111″** and **21″**, of the same respective elements, both being assumed to be sharp; in a downswing of the reed these causes and effects are precisely reversed.

In connection with the foregoing and the next succeeding paragraphs, it will be found convenient to refer, instead of to FIGURE 2, to FIGURE 2*a*, which is a fractional enlargement of the former.

I have found that if either both the bottom and top marginal portions of the reed face principally influencing the pick-up (in this structure, portions **111′** and **111″** of the face **11***a* of projection **11**), or both the bottom and top marginal portions of the pick-up face facing the vibratory locus of the above-mentioned reed face (in this structure, portions **21′** and **21″** of the pick-up face

21*a*), be inclined toward their outer limits (i.e., bottom and top limits, respectively) away from the direction in which the respective face faces, then this varying-pitch or "meow" component disappears. This I believe is due to the fact that either of such techniques relieves the sharpness of the above-mentioned angles otherwise formed in the oscillation peaks—coupled with the propositions (1) that very sharp oscillation-peak angles maximize the opportunity for the not-strictly-rigorous repitition of cyclic waveform to result in the generation of an inharmonic component, and (2) that the inharmonic component most readily generated is one having a pitch dependent on the velocity of the reed. This inclining is illustrated in FIGURES 2 and 2*a* for the marginal portions (**111'** and **111''**) of the reed (projection) face **11***a* in the form of a rounding of each of those marginal portions, and is illustrated in the alternative FIGURE 3 for the marginal portions of the pick-up face **21***a* in the form of a bevelling of each of those marginal portions (which are accordingly renumbered **221'** and **221''**)—it being understood that the choice of bevelling in the one case and of rounding in the other is an arbitrary one.

It may be noted that in any tone, or in any later portion of a tone, in which the top of the active reed portion (e.g., projection **11**) does not pass beyond the top of the pick-up **21**, the immunization of the tone against the generation of the component under discussion would be fully achieved by the inclining of either one only of the bottom marginal portions of reed (projection) face and pick-up face respectively. While in such instances the component may tend not to reach, or tend by that point in the tone to have passed below, the threshold of discernibility, nevertheless this limited embodiment of my invention—illustrated in FIGURE 4, for example by the rounding of the bottom marginal portion of the pick-up face **21***a* only (which portion is accordingly renumbered **121'**)—is to be recognized as having utility.

A particular case is presented if both the pick-up and the reed portion principally influencing it (in this structure, projection **11**) are of essentially similar thicknesses in the direction of reed vibration. In this particular case—unlike that where either one is substantially thicker than the other—the relatively flat tops, of the two similarly directed oscillation peaks per fundamental cycle, will have essentially disappeared, and a single angle—quite sharp in the absence of the inclining of marginal face portions discussed above—will be formed between the approach side and the recession side of the peak. The techniques already described are fully applicable to relieve the sharpness of this single angle, and to obviate the generation of the varying-pitch component, in this particular case. There is alternatively available for this purpose, however, a further technique: an inclining, of the nature mentioned above, of correspondingly directed (i.e., both upper, or both lower) marginal portions of the reed face **11***a* and the pick-up face **21***a*. This particular dimensional case and this particular alternative technique have been illustrated in FIGURE 5 (in which because of reduced thickness the pick-up and its face are designated as **321** and **321***a* respectively)—by way of example, by the rounding of the lower marginal portions of the respective faces (which are accordingly designated **121'** and **111'** respectively).

It will of course be understood that if there be employed for the reed a second pick-up, such as **22** associated with reed portion (projection) **12**, the appropriate marginal face portions of this pick-up and/or associated reed portion should be treated similarly to those of the first pick-up and/or associated reed portion.

In the structure of FIGURES 1 and 2 the mean vibratory locus of the portion of the reed principally influencing the pick-up is substantially cylindrical and has an inner boundary faced by the pick-up and moved toward the pick-up by the dynamic shortening of the reed. It is to be understood that this general embodiment of my invention is itself subject to many variations one of which I have illustrated in FIGURES 6 and 7. In the structure of these figures the reed, in view of its being substantially wider, is designated as **9**; it may be impulsively excited, for example from below, silimarly to the reed of FIGURES 1 and 2. The portion of the reed **9** which principally influences the pick-up is an internal edge portion, created for example by piercing the reed with a somewhat longitudinally elongated hole **8**. The outer part (i.e., the part further away from the fixed extremity of the reed) of the peripheral face of the hole is, as illustrated, arcuate, and it is the central region **8***a* of this part of the hole's peripheral face to which the pick-up is closely spaced and which principally influences it. This region **8***a* is preferably at the node for the reed's second-partial vibration, for reasons made apparent above.

The pick-up is illustrated as a stationary horizontally disposed disc electrode **23**, typically of thickness about the same as that of the reed, and for example formed at the bottom extremity of a downhanging arm or rod **24**. As seen in the plan view of FIGURE 6, it is closely spaced from the region **8***a*, and by virtue of its smaller size than the hole **8** is much less influenced by all other regions around the hole periphery than by **8***a*. Vertically the pick-up **23** may for example be so adjusted, as seen in FIGURE 7, that its bottom is approximately at the level of the central horizontal plane of the reed when that is in its rest position. To immunize the system against the generation of a spurious variable-pitch component the peripheral surface of the pick-up **23** may be inclined, at bottom and top, away from the vibratory locus of **8***a*, as indicated at **23'** and **23''**; this may for example be done by forming that whole peripheral surface as a vertically slightly convex one.

Obviously the locus of vibration of the region **8***a*, while technically caused by the curvature of this region as seen in plan to be of a fractional toroidal configuration, is still substantially cylindrical, and has an inner boundary faced by the pick-up and moved toward the pick-up by the dynamic shortening of the reed, thereby during that shortening to increase the efficiency of translation of oscillations by the pick-up.

It will be observed that in connection with FIGURES 6 and 7 and with earlier figures I have shown the pick-up slightly displaced upwardly from the rest position of the reed, with the result that the very minimum direct capacity between reed and pick-up achieved in the fundamental cycle is at the peak of downswing of the reed. A reason for my preferring this is that the pick-up-supporting arms (e.g., **20, 24**) have been shown as approaching the reed's rest position from above; when the reed is at the peak of upward swing, small reed-to-supporting-arm capacity (which it is desirable to minimize as much as practicably may be done) will slightly raise whatever low reed-to-pick-up capacity would otherwise be achieved at this point; and it is better than this raising not affect the above-mentioned very minimum reed-to-pick-up capacity—which is accordingly made to occur at the downswing peak, by making upward the slight displacement of pick-up from reed rest position. It will however be understood that usually these are refinment, or second-order, considerations, and that the structures are normally very satisfactorily operable with the pick-up slightly displaced downwardly, instead of upwardly, from the reed rest position. A readjustment of the structure of FIGURES 6 and 7 to this state of affairs is illustrated in FIGURE 7*a*.

With reeds of certain characteristics (in respect of material, dimensions, etc.) it is sometimes found that the magnitude of the dynamic shortening on the strongest excitations is unfavorably large for the structures thus far described. This may be understood by recalling that even on the strongest excitations, or with maximum dynamic shortening, the pick-up must remain out of the vibratory locus—i.e., must be confined on the reed's-fixed-extremity side of the nearer of the two boundaries of that locus—and

if the dynamic shortening is of large magnitude the result is that that boundary, at small vibration amplitudes, has retreated sufficiently far from the pick-up to cause an excessive decrement of, as well as abnormally low later harmonic development in, the translated oscillations. FIGURES 8 and 9 illustrate a structure by which any desired reduction of effect of the dynamic shortening may be achieved.

In these figures two musically successive reads **10** are shown. Each of these is provided with a pair of projections **13**, each pair being conveniently in the form of a V of round cross-section metal wire, laid flat on top of the respective reed with the apex (which may be rounded) of the V pointing toward the fixed end of the reed and secured on top of the reed as by welding or soldering. The projections proper are of course formed by the portions of the V overhanging the edges of the reed; their surfaces **13***a* facing generally toward (as distinguished from away from) the fixed extremities of the reeds are those to which the respective picks-ups are closely spaced and which respectively influence the pick-ups.

Inherently the projection from one reed toward a second approaches the projection from the second toward the first, and for each of such pairs of mutually approaching projections a unitary pick-up structure—though actually embodying two pick-ups **25**—may be provided. This unitary structure may for example be formed of a length of metal ribbon whose major cross-sectional dimension will be arranged parallel to the direction of vibration of the reeds (e.g. vertically) and may for example be somewhat greater than the diameter of the wire of which the reed projections are formed. The center of each length of metal ribbon may be formed into an eye **26**, and may be gripped by and above the head **27***a* of a respective screw **27** screwed upwardly through that eye into a respective downhanging post **28** whose axis passes between the respective pair of reeds somewhat nearer to their fixed extremities than are the projections **13**. A washer **27***b* may intervene between eye **26** and screw-head **27***a*, if desired. From the eye **26** one half of the length of metal ribbon may pass horizontally, diagonally toward one reed of the respective pair and away from the reed's fixed extremity, until it approaches the nearer projection **13** from that reed, and may then be bent into parallelism and close spaced relation to that projection; the other half of the ribbon may be correspondingly directed and formed with respect to the nearer projection **13** from the other reed of the pair—the last run in each half of the ribbon forming the pick-up proper **25**. In the direction of the length of the reed the juxtaposed surfaces of each pick-up and the respective reed projection are preferably at the node for the second-partial vibration of the reed from which that projection extends. Vertically the ribbon may for example be so mounted and adjusted that the bottom of each pick-up is approximately at the level of the center of the wire forming the respective reed projection. The system is immunized against the generation of a spurious variable-pitch component by the inclining, at top and bottom of each surface **13***a*, of that surface away from its vibratory locus which is inherent in the round cross-section of the wire of which each projection is formed.

Obviously the vibratory locus of the surface **13***a* is truncatedly conical; its inner boundary is faced by the pick-up; and that inner boundary, being moved lengthwise of the reed by the dynamic shortening, is by that shortening moved toward the pick-up. In view of the diagonal arrangement of the pick-up surface and the reed vibratory locus, however, the change of spacing between the pick-up and the inner boundary of the vibratory locus is not as great as the movement of that inner boundary in the direction of reed length. Actually the change of spacing is the product of that movement by the cosine of the angle of disposition of the surface **13***a* relative to the direction of reed length; that change of spacing by the dynamic shortening is therefore readily controlled by choice of that angle, and accommodation to any specific reed characteristics and desired magnitude of result is readily achieved.

In the structure of FIGURES 8 and 9 it will be seen that each pick-up face juxtaposed to a respective reed surface **13***a* extends, in the direction of reed length, not more than about 2½ times its extent in the direction (vertical) of reed vibration; 2½ is approximately the cotangent of 22 degrees.

In the foregoing embodiments of my invention the effect of the dynamic shortening has been to move the inner boundary of the vibratory locus of the pick-up-influencing portion of the reed toward the pick-up, and it is this movement which has been basically relied on to increase the exposure of pick-up to reed, the interception of the pick-up field by the locus, and thus the translation efficiency. In FIGURES 10 and 11 I show an embodiment of my invention in which the movement of the inner boundary of the vibratory locus does not alter the spacing of the locus from the pick-up—but does increase the area of the locus faced by the pick-up, thereby likewise increasing the abovementioned exposure, interception and translation efficiency.

In these figures the metallic reed is again designated as **10**; it may be impulsively excited, for example from below, similarly to the reeds of the earlier figures. Secured transversely across the top of the reed, as by welding or soldering, and slightly overhanging the reed on each side, is a thin metal rod **14** each end of which is enlarged to form, or is otherwise provided with, a thin metal disc **15** transverse of the rod and thus lying in a plane parallel to the direction of reed vibration. The very inner small portion (i.e., portion closest to the fixed extremity of the reed) of each of these discs **15** is preferably positioned, lengthwise of the reed, at the node for the second-partial vibration of the reed.

For each of the discs **15** there is provided a respective pick-up **29**. This may for example be in the form of a stationary short metallic-cylinder electrode having an axis parallel to that of the rod **14**, and typically of diameter similar to that of the respective disc **15**; its end surface further from the reed may for example be provided with a deep vertical cut **29'** admitting the lower end portion of a rod **30** by which the pick-up may be supported, the pick-up being crimped about and/or welded or soldered in place on the rod. Lengthwise of the reed the pick-up may be positioned so that it lies generally toward the fixed extremity of the reed from the disc but is overlapped in minor degree by the small-vibration-amplitude vibratory locus of the surface of the disc; in the direction (vertical) of reed vibration its center may be located slightly above the position occupied by the center of the disc when the reed is in rest position; and transversely of the reed its reed-ward surface **29***a* is located in close spaced relation to the plane in which the outside surface **15***a* of the respective disc **15** vibrates.

It will be understood that when the reed is in its rest position the capacity between a disc **15** and the respective pick-up **29** is principally determined by the overlapped portions of those two elements, considered as seen in FIGURE 11 wherein they appear as slightly overlapped circles. Although the geometry is specifically different from that of the elements in FIGURES 1 and 2, it will nevertheless be understood that upon vibration of the reed the nature of the variation of capacity between it (i.e., its portions **15**) and the associated pick-ups will be basically similar to that above described in connection with those earlier figures. This is subject to the qualification that because the peripheries of the surfaces **15***a* and **29***a* are smoothly curved in their overlappable portions, the top of each of the two similarly directed peaks per fundamental oscillation cycle will in general be an inverted U smoothly continuing from the approach side and smoothly continued by the recession side of the

peak—thus by geometry specifically somewhat different avoiding in each peak any sharp angle which might lead to the spurious variable-pitch or "meow" component.

It will of course be understood that the structure of FIGURES 10 and 11 (as well as the structure of FIGURES 8 and 9) has been made to include two pick-ups per reed, on respective sides of the reed. As brought out for the two-pick-ups-per-reed structure of FIGURES 1 and 2, this is not indispensible, but is preferred (and somewhat more so in connection with these later pairs of figures, in view of the greater influence on the pick-ups of possible lateral reed vibrations) for essentially "proofing" the system against undesirable effects of unintended lateral reed vibrations.

It will be understood that in the structure of FIGURES 10 and 11 the portion of the reed to which the pick-up is principally responsive is constituted by the surfaces **15***a*. The low-vibration-amplitude vibratory locus of either one of these surfaces is a flat annular surface (i.e., the planar space between the larger and the smaller of two concentric circles) whose inner and outer boundaries are formed by the innermost and outermost peripheral points on the pick-up surface **15***a*; the pick-up faces a restricted inner portion only of the locus. The inner boundary of the locus is shifted toward the fixed extremity of the reed (i.e., is made to become a still smaller inner circle) by the dynamic shortening, with the result that the pick-up then faces a larger portion of the locus. In this structure it is the increase in area, of the locus, faced by the pick-up (instead of an increase in proximity of locus to pick-up) by the dynamic shortening which increases the translation efficiency.

Such an increase in area may be used in combination with an increase in proximity; FIGURE 12 illustrates an arrangement involving such joint utilization. The structure of this figure may be quite similar to that of FIGURES 10 and 11, excepting that the active surface of each reed portion **15** and the active surface of each pick-up electrode **29** is made slightly convex, or for example spherical as indicated by **15***b* and **29***b* in the figure, rather than flat (as are **15***a* and **29***a* of the prior figures). Obviously the convex shaping—which itself obeys the specifications set forth above, in connection with early figures, as to inclining of surfaces—itself provides an independent (and additional) proofing against variable-pitch components.

It will readily be appreciated that the vibratory locus of the inner half (i.e., that toward the fixed extremity of the reed) of each surface **15***b* is substantially truncatedly conical; that it has an inner boundary of which in the absence of dynamic shortening a restricted inner portion only, and in the presence of such shortening a larger portion, is faced by the pick-up, thereby effecting the area-increase action described above in connection with FIGURES 10 and 11; and that moreover the inner boundary of the locus is moved by the dynamic shortening into closer spacing to the pick-up, thereby effecting the proximity-increase action described above in connection with still earlier figures.

The active reed portions and the pick-ups need not be limited to circular ones in such structures as those of FIGURES 10–11 and 12. Their peripheries may for example have angles in the significant (i.e., overlappable) portions, with resultant sharpening of the oscillation peaks; especially is this permissible, without risk of generation of a variable-pitch component, if their active surfaces be convex as illustrated in FIGURE 12. Thus in FIGURE 13 I have illustrated the peripheries of **15***b* and of **29***b* ground off along each of two intersecting inclined planes to form, in their overlappable portions, the angles **15***c* and **29***c*. This figure also illustrates a slight lowering and slight outward displacement of the pick-up surface **29***b* in order that, in spite of the reshaping of the peripheries, there will still be a slight overlap of **15***b* with it in the rest position of the reed, which I consider as a general rule desirable.

As to any of the illustrated embodiments of my invention it will be appreciated that the pick-up may be viewed as having a vibration-sensing field of which a part—i.e., that extending from the pick-up in directions generally away from the fixed extremity of the reed—diminishes in sensitivity with increasing distance from that extremity, and that it is in that part of the field that the pick-up-influencing reed portion is principally disposed and vibrates. In another generic sense, the pick-up-influencing portion of the reed may be viewed as being disposed at least predominately beyond the pick-up from the reed's fixed extremity.

It will be understood that while I have disclosed my invention with particular reference to capacitative pick-ups, no unexpressed limitation thereto is necessary or intended, since obviously it may equally well be applied to pick-ups of the magnetic or other types. And generally, while I have disclosed my invention in terms of specific embodiments 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 not necessarily constitute a departure from the scope of the invention, which I undertake to express in the appended claims.

I claim:

1. For use in a musical instrument, an electric tone generator comprising in combination, a vibratory reed, mounting means supporting said reed at one end thereof so that the reed cantilevers freely away from the mounting means, said reed being shaped in transverse section to substantially restrict vibration of the reed to a path parallel to a single plane of vibration extending longitudinally along the reed, mechanical impulse exciting means coacting with said reed to impulsively excite the latter for free vibration in said path, means on said reed located a substantial distance from said one end thereof and defining a thin tone generating edge exposed toward said one end of the reed and extending laterally with respect to the reed at a substantial angle to said plane to be carried by the reed through a path which is cyclically moved toward said one end of the reed by upper partial vibration of the reed, and an electrical pickup defining a pickup face confronting said tone generating edge in generally conforming relation thereto to be vibrationally passed by said edge upon vibration of the reed.

2. In an electric tone generator, the combination of a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to substantially restrict vibration of the reed to a path parallel to a single plane of vibration extending longitudinally along the reed, mechanical impulse exciting means coacting with said reed to impulsively excite the latter for free vibration in said path, means on said reed located a substantial distance from said one end thereof and defining a tone generating surface exposed toward said one end of the reed and being turned at a substantial angle relative to a prependicular to said plane to be moved by the reed through a path which is cyclically moved toward and away from said one end of the reed by upper partial vibration of the reed, a pickup defining a pickup face surface disposed in generally confronting relation to said tone generating surface and generally conforming to the latter to be vibrationally passed by said tone generating surface upon vibration of said reed, and said pick-up being positioned in relation to the position of said tone generating surface when the reed is in its rest position to space the center of said pickup face surface from the center of said tone generating surface toward said one end of the reed whereby the displacement of the vibratory path of said tone generating surface toward said one end of the reed due to upper partial vibration of the reed

decreases the mean effective spacing of said pickup face surface from said tone generating surface.

3. In an electric tone generator, the combination of a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to substantially restrict vibration of the reed to a path parallel to a single plane extending longitudinally along the reed, mechanical impulse exciting means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness which is only a fraction of the width of the reed whereby the reed is caused to vibrate at its upper partial frequencies at amplitudes sufficient to cause marked dynamic shortening of the reed, means on said reed located a substantial distance from said one end thereof and defining a tone generating face exposed toward said one end of the reed and being turned at a substantial angle relative to a perpendicular to said plane to be carried by the reed through a path which is cyclically moved toward and away from said one end of the reed upon upper partial vibration of the reed, a pickup defining a pickup face disposed in generally confronting relation to said tone generating face and generally conforming to the latter to be vibrationally passed by said tone generating surface upon vibration of said reed, and said pickup being positioned in relation to the position of said tone generating face when the reed is in its rest position to space the center of said pickup face from the center of said tone generating face toward said one end of the reed whereby the displacement of the vibratory path of said tone generating face toward said one end of the reed due to upper partial vibration of the reed decreases the spacing of said center of said tone generating face from said pickup face center.

4. For use in a musical instrument, electrical tone generating means comprising, in combination, a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to restrict vibration of the reed substantially to a path parallel to a single plane of vibration extending longitudinally along said reed, hammer means coacting with said reed to impulsively excite the latter for free vibration in said path, means on said reed located a substantial distance from said one end thereof and defining a tone generating surface turned at a substantial angle to a perpendicular to said plane to be carried by the reed through a path which is cyclically moved toward and away from said one end of the reed by upper partial vibration of the reed, an electrical pickup defining a pickup face surface confronting said tone generating surface in generally parallel relation thereto to be vibratorily passed by said one generating surface upon vibration of the reed, said pickup being located to space the center of said pickup face surface from the center of said tone generating surface toward said one end of said reed when said reed is in its rest position, and at least one of said surfaces having a width in the direction of reed vibration which has a minimum value at the edge of said one surface proximate the center of the other surface and which increases in the direction in which the center of said one surface is spaced from the center of said other surface.

5. For use in a musical instrument, electrical tone generating means comprising, in combination, a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to restrict vibration of the reed substantially to a path parallel to a single plane of vibration extending longitudinally along said reed, mechanical impulse means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness sufficiently limited in relation to the width of the reed to provide upon excitation of the reed for upper partial vibration of the reed at amplitudes sufficient to effect a marked dynamic shortening of the reed, electrically effective means on said reed located a substantial distance from said one end thereof and defining a tone generating surface turned at a substantial angle to a perpendicular to said plane to be carried by the reed through a path which is cyclically moved toward and away from said one end of the reed by upper partial vibration of the reed, an electrical pickup defining a pickup face surface confronting said tone generating surface to be vibratorily passed by said tone generating surface upon vibration of the reed, at least one of said surfaces being convex outwardly toward the other surface, and said pickup being positioned to space the center of said pickup face surface from the center of said tone generating surface toward said one end of said reed when said reed is in its rest position whereby dynamic shortening of said reed due to upper partial vibration thereof causes the center of said tone generating surface to move toward the center of said pickup face surface.

6. Electrical tone generating means comprising, in combination, a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to restrict vibration of the reed substantially to a path parallel to a single plane of vibration extending longitudinally along said reed, hammer means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness limited sufficiently in relation to the width of the reed to provide upon striking of the reed by said hammer means for upper partial vibration of the reed at amplitudes sufficient to effect a marked dynamic shortening of the reed, electrically effective means on said reed located a substantial distance from said one end thereof and defining a generally flat tone generating surface substantially parallel to said plane and carried by the reed through a path which is cyclically moved toward and away from said one end of the reed by upper partial vibration of the reed, an electrical pickup defining a pickup face surface of extensive width confronting said tone generating surface in generally parallel relation thereto to be vibratorily passed by said tone generating surface upon vibration of the reed, said pickup being positioned to effect when said reed is in its rest position an overlapping relationship of said surfaces in which the center of said pickup face surface is spaced from the center of said tone generating surface toward said one end of said reed, and at least one of said surfaces having a width in the direction of reed vibration which has a minimum value at the edge of said one surface proximate the center of the other surface and which increases from said minimum value in the direction in which the center of said one surface is spaced from the center of said other surface.

7. In an electrical tone generator, the combination of a vibratory reed, mounting means supporting said reed at one end thereof so that the reed cantilevers freely away from the mounting means, said reed being shaped in transverse section to substantially restrict vibration of the reed to a path parallel to a single plane extending longitudinally along the reed, hammer means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness which is limited sufficiently in relation to the width of the reed to provide upon striking of the reed by said hammer means for upper partial vibration of the reed at amplitudes sufficient to effect a marked dynamic shortening of the reed, means on said reed located a substantial distance from said one end thereof and defining an electrically effective tone generating face exposed toward said one end of the reed and extending laterally with respect to the reed to be carried by the reed through a path which is cyclically moved toward and away from said one end of the reed by upper partial vibration of the reed, and an electrical pickup defining a pickup face confronting said tone generating face to be vibrationally passed by said tone generating

face upon vibration of the reed and to be approached by said tone generating face upon dynamic shortening of the reed.

8. In electrical tone generating means, the combination of a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to restrict vibration of the reed substantially to a path parallel to a single plane of vibration extending longitudinally along the reed, hammer means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness limited relative to the width of the reed to provide upon striking of the reed by said hammer means for upper partial vibration of the reed at amplitudes which effect a marked dynamic shortening of the reed, electrically effective means on said reed located a substantial distance from said one end thereof and defining a tone generating face surface turned at a substantial angle to a perpendicular to said plane to be carried by the reed through a path which is cyclically displaced toward and away from said one end of the reed by upper partial vibration of the reed, an electrical pickup defining a pickup face surface confronting said tone generating face surface and having a substantial width in the direction of reed vibration, said pickup face surface being positioned relative to the rest position of said tone generating face surface to be vibratorily passed by the latter surface upon vibration of the reed, and said pickup being located to space the center of said pickup face surface from the center of said tone generating surface toward said one end of said reed when said reed is in its rest position.

9. In an electric tone generator, the combination of a vibratory reed, mounting means supporting said reed at one end thereof to cantilever freely away from the mounting means, said reed being shaped in transverse section to substantially restrict vibration of the reed to a path parallel to a single plane of vibration extending longitudinally along the reed, mechanical striking means coacting with said reed to impulsively excite the latter for free vibration in said path, said reed having a thickness limited relative to the width of the reed to provide upon excitation of the reed by said striking means for upper partial vibration of the reed at amplitudes sufficient to effect marked dynamic shortening of the reed, electrically effective means on said reed located a substantial distance from said one end thereof and defining a tone generating face surface turned at a substantial angle relative to a perpendicular to said plane to be carried by the reed through a path which is cyclically displaced toward and away from said one end of the reed by upper partial vibration of the reed, a pickup defining a pickup face surface disposed in generally confronting relation to said tone generating surface, said pickup being positioned to locate the center of said pickup face surface in a position displaced somewhat in the direction of reed vibration from the center of said tone generating face surface when said reed is in its rest position, at least one edge of one of said face surfaces extending longitudinally with respect to said reed and being relieved away from the opposed face surface, and said pickup being positioned relative to the position of said tone generating face surface when the reed is in its rest position to space the center of said pickup face surface from the center of said tone generating face surface toward said one end of the reed whereby the displacement of the vibratory path of said tone generating face surface toward said one end of the reed due to dynamic shortening of the reed by upper partial vibration thereof decreases the spacing of the center of said tone generating face surface from the center of said pickup face surface.

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