

Jan. 2, 1934.

M. L. SEVERY

1,941,870

ELECTRICAL MUSICAL INSTRUMENT

Filed May 28, 1929

4 Sheets-Sheet 1

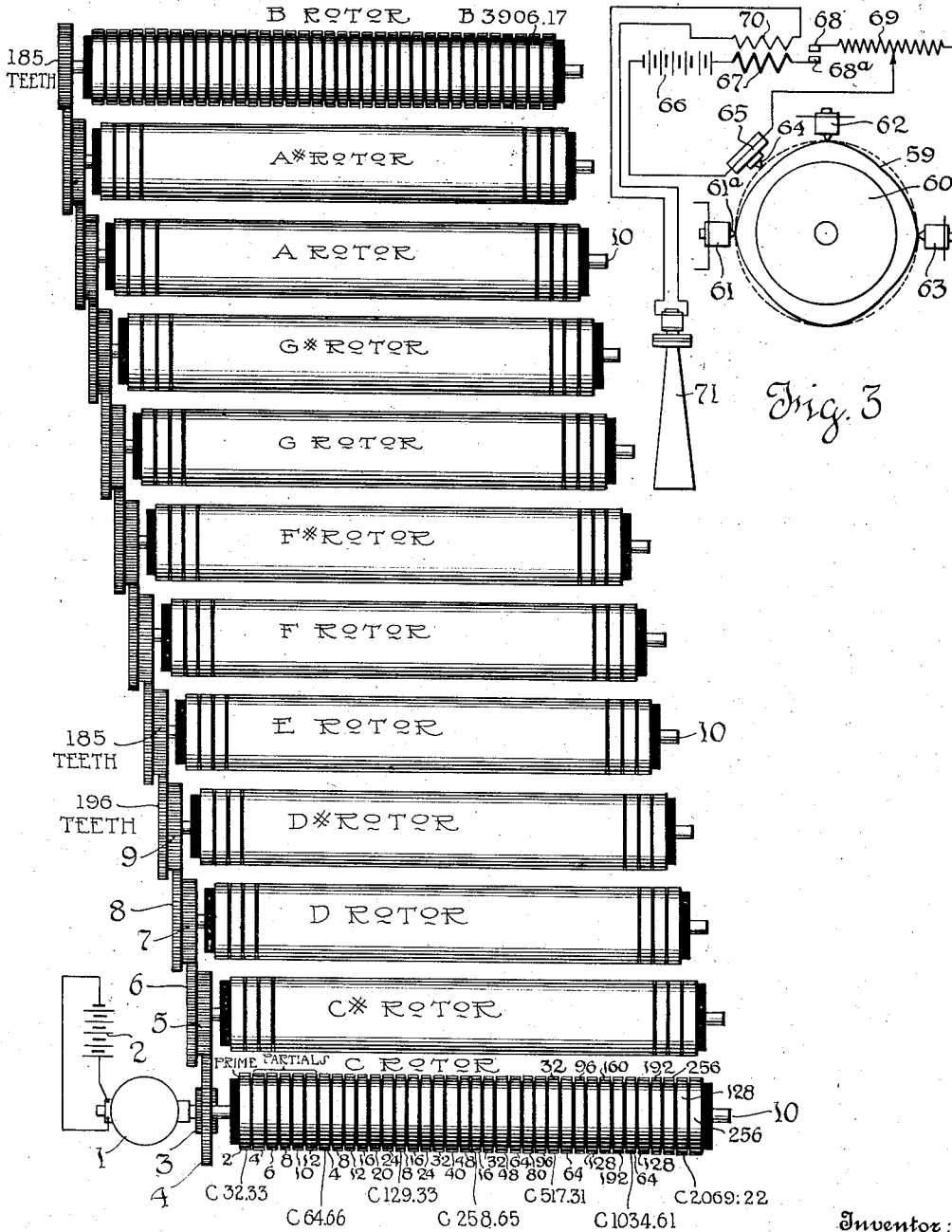


Fig. 1

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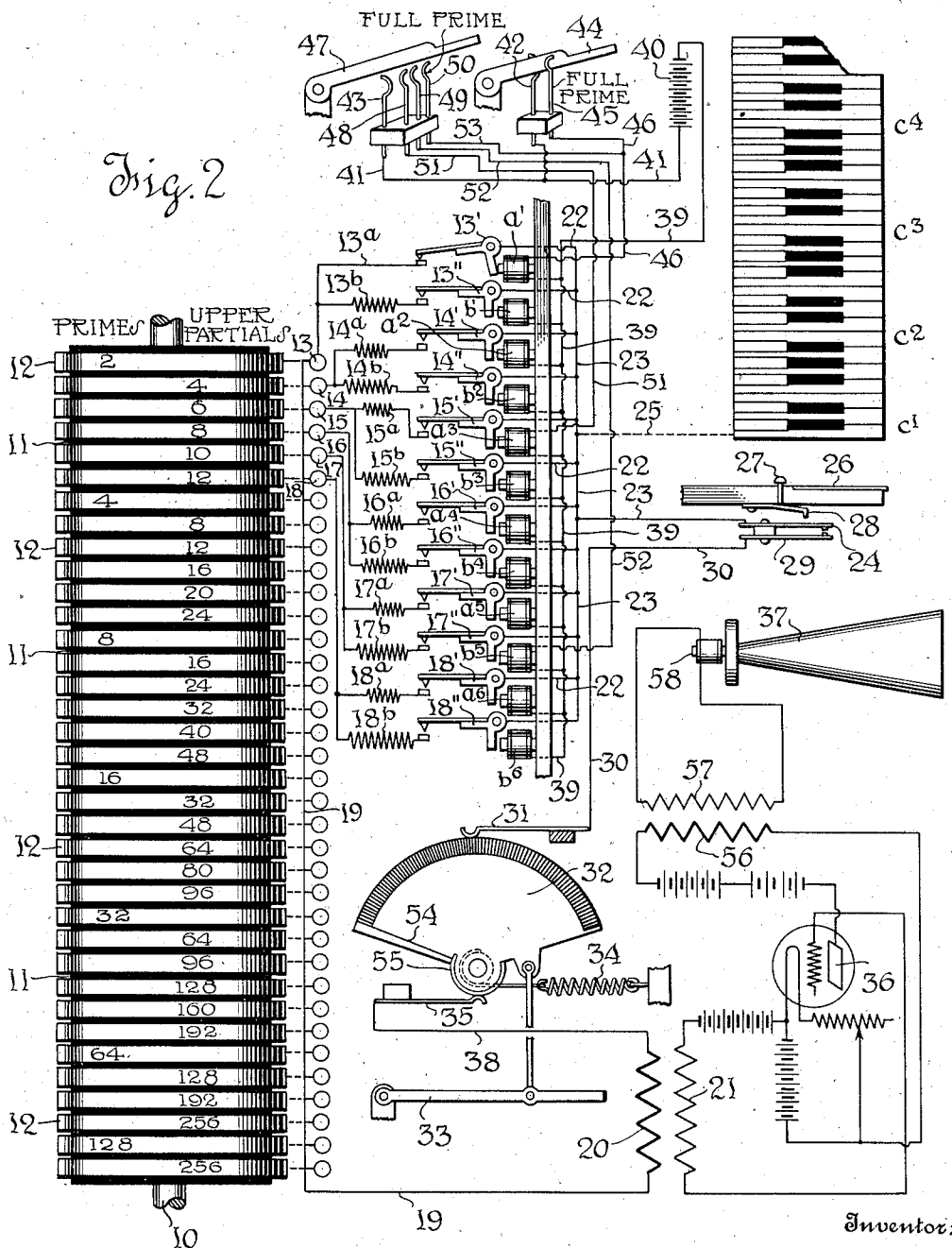
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ELECTRICAL MUSICAL INSTRUMENT.

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4 Sheets-Sheet 2



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4 Sheets-Sheet 3

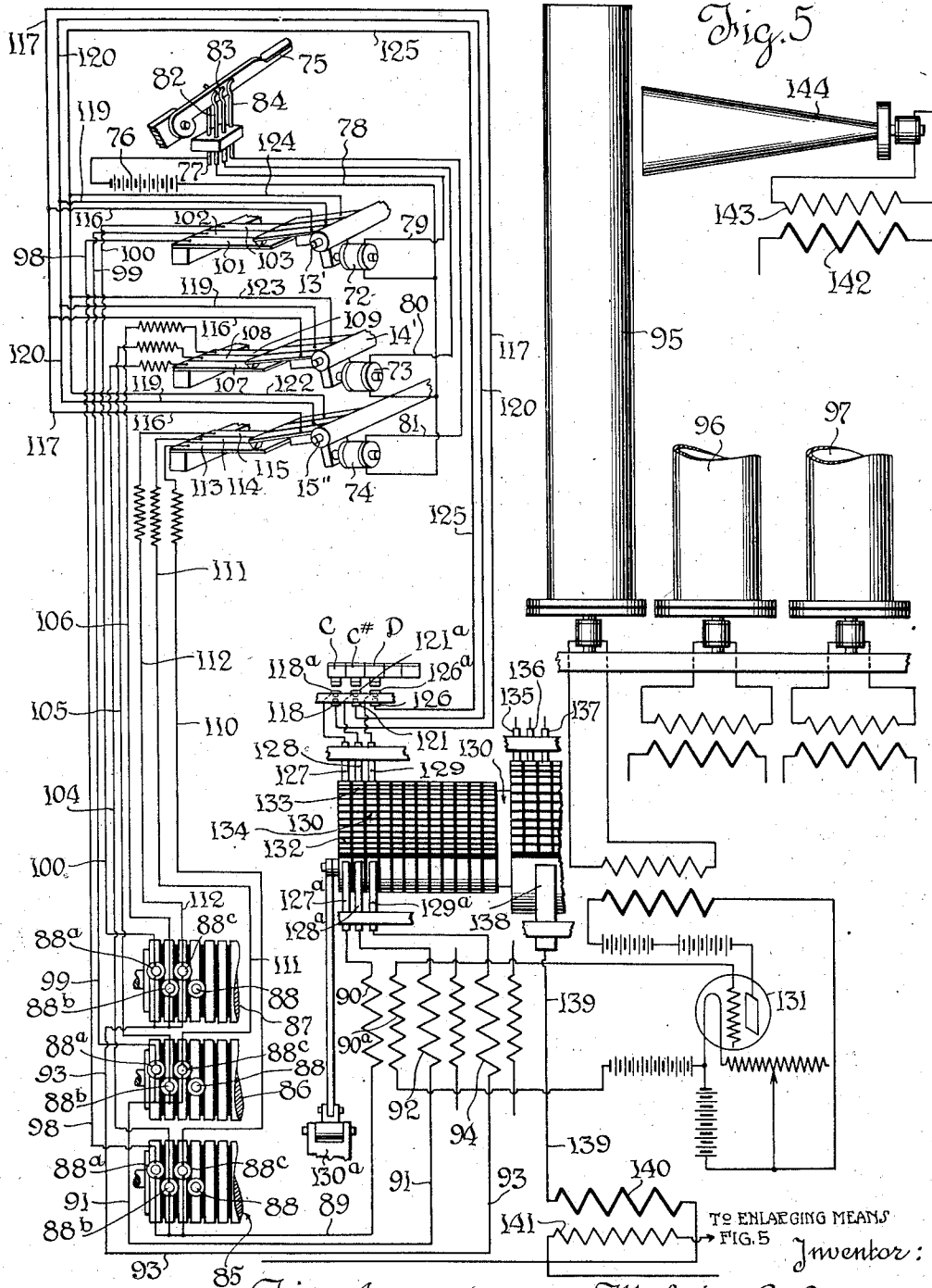
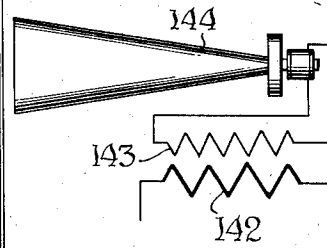


Fig. 5



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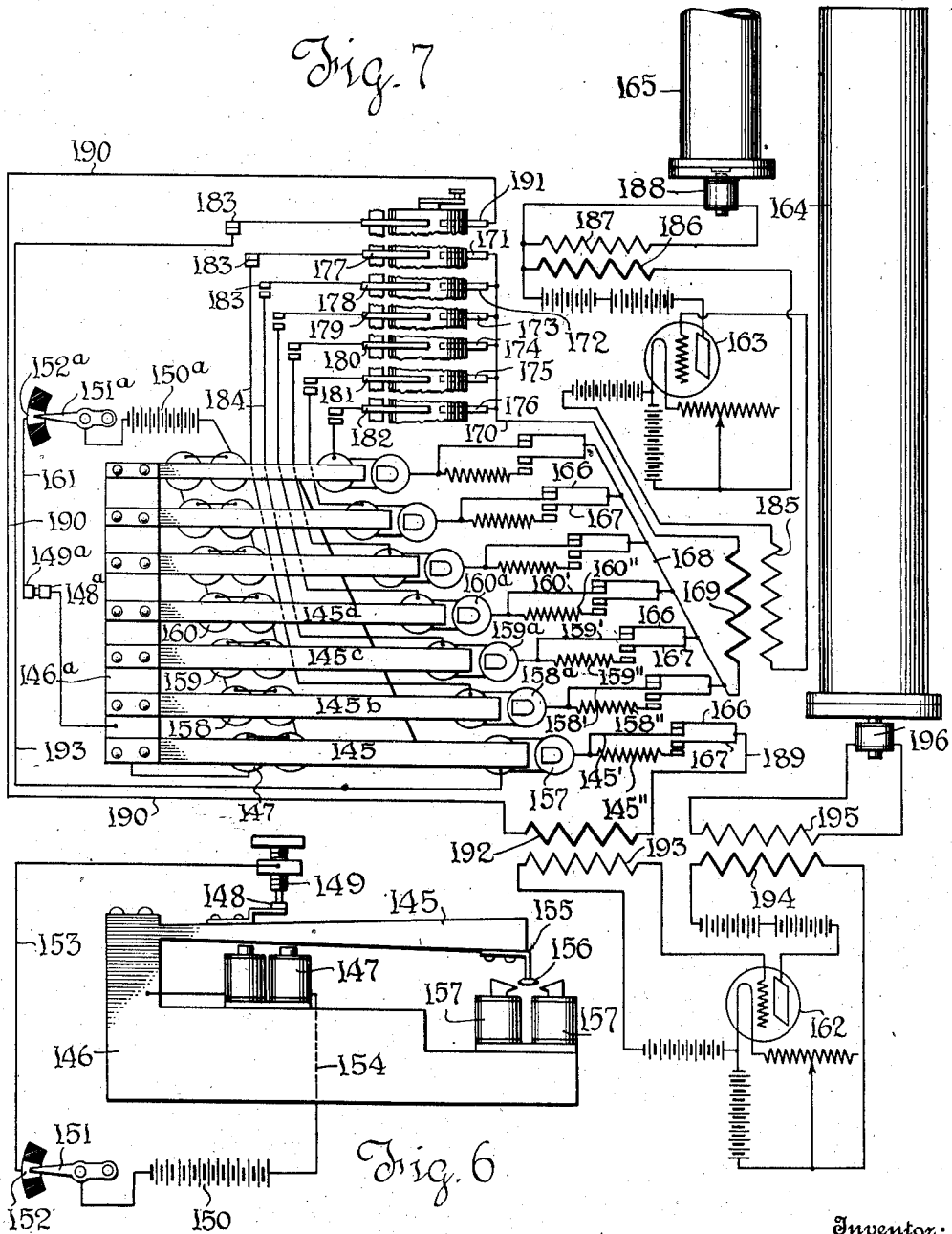
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ELECTRICAL MUSICAL INSTRUMENT

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4 Sheets-Sheet 4

Fig. 7



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UNITED STATES PATENT OFFICE

1,941,870

ELECTRICAL MUSICAL INSTRUMENT

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Application May 28, 1929. Serial No. 366,661

9 Claims. (Cl. 84—1)

This invention relates more particularly to a musical instrument having one or more qualities of tone for each of the various pitches of its range, each note of given quality being derived from electrical undulations set up by moving members. Each of these members is adapted to produce electrical pulsations of proper wave-form, and of a frequency corresponding to that of some one of the partials of the note of the gamut with which it is most commonly associated. The electrical pulsations produced by the moving members commonly associated with any particular key of the manual are capable of selection as to periodicity and of gradation as to relative strength, and are further capable of expressional gradation as a whole, at the will of the player. As a result, an electrical wave-form is produced having the characteristics of the wave-form of the predetermined pitch and timbre of the tone desired, this wave-form being capable of translation into such tonal quality and pitch, and of being used in the proper rendition of musical compositions.

An important object of this invention is the production of a relatively small, cheap, compact, durable, and dependable musical instrument adapted to generate electrical wave-forms of characteristics depending upon the sonorous results desired; to enlarge, and control the enlargement of, such wave-forms at the will of the player; and to translate them without appreciable distortion into sonorous vibrations of the timbre, pitch and power desired for the proper rendition of the particular composition in hand.

Another important object of this invention is the provision of means whereby a more effective bass may be produced from electrical wave-forms than has heretofore been attained.

Still another important object is the provision in an instrument of this type of means for producing truer tones of more satisfying volume than has heretofore been possible in any instrument using electrical enlargement.

Another object of the invention is the production and convenient grouping of indestructible electrical wave-generators adapted to produce all of the partials comprising all of the various timbres of the instrument.

Other features of the invention pertain to the partial selective system, the controlling of the relative intensities of the partials of each quality, and various further details which will be duly explained herein.

As set forth in my companion application, Serial No. 329,647 filed December 31, 1928, now Patent No. 1,893,250, dated January 3, 1933, in musical instruments making use of a scale tuned in equal temperament, and depending for the musical pitches of such scale upon rotating members producing pulsations, all such pulsations, including those representing the well-known in-

commensurate ratios subsisting between certain notes of each octave, can be secured with an accuracy sufficient for all practical purposes by the employment of six rotating cylinders or timbre-form-carrying rotors, for an instrument of a range of seven octaves, and such an arrangement of rotors forms one of the embodiments of my present invention. There is, however, another embodiment in which twelve rotors or timbre-form-carrying cylinders are used, one for all of the notes C and their partials; another for all of the C# notes and their partials; a third for all of the notes D and their partials, and so on up to and including the twelfth rotor, which will care for all of the notes B and their partials.

Both of these forms are equally within the province of my invention, but as I have shown the six-rotor grouping in said companion application, and further, because the twelve-rotor grouping lends itself so much more readily to easy showing and explanation, I have detailed said grouping in the present application as one means for generating the desired simple electrical waves forming the partials used in the musical instrument herein described.

The grouping, gearing, and governing of this twelve-rotor arrangement are clearly set forth in U. S. Patent No. 1,156,329 to E. G. Thomas, issued October 12, 1915, and I have therefore reproduced herein only those details necessary to a complete exposition of my invention.

In my preferred construction I make use of integral timbre-forms, save where laminated timbre-forms punched from suitable material would be cheaper, each said timbre-form ordinarily producing a single partial of a tone-color of definite pitch. These I prefer to group, in the main, in the order of the partials, a C-rotor carrying at one end the prime of 32.33 vibrations, followed in order by the second, third, fourth, fifth and sixth partials of that note C, after which would come the prime of 64.66 vibrations and its partials in their respective order, and so on to the highest note C of the instrument and its respective partials. It is obvious that any desired number of partials may be used, but for a moderately-priced instrument six are ordinarily sufficient, and I have shown that number rather than confuse principles by too great an extension of their application.

It will be noted that each of the twelve rotors is the exact duplicate of all the others with regard to the pulsation-producing timbre-forms carried thereby, and that in each rotor some of the forms occur a plurality of times. It is obvious that a single-timbre-form might be used to generate a plurality of separate series of pulsations, thus somewhat cheapening the instrument. I contemplate taking advantage of this saving, since it is clearly within the purview of

my invention, but in order to avoid complicating the drawings herein I have merely called attention thereto, and do not illustrate or describe the same in detail.

5 In addition to its broader features, my invention embraces certain details of design and of mechanical construction whereby the player is given complete control of all of the musical factors necessary to the highest type of artistic interpretation, and these will be pointed out hereinafter.

10 The twelve-rotor form of my invention illustrated herein embodies, as its moving electrical wave-generators, twelve cylinders each carrying an identical arrangement of timbre-forms, and capable with their associated parts, of producing at will a great number of different tonal timbres. To avoid needless complexity, the instrument is shown as having only one manual, but it is obvious that two, three or more manuals may be served from the identical rotors and timbre-forms shown, as set forth in Fig. 3, or by the mere multiplication of the necessary timbre-forms. I contemplate such multi-manual instruments where desired, and as they are merely obvious extensions of what is herein shown, they come well within the scope of my invention.

In the accompanying drawings:

Fig. 1 is an elevation showing the twelve rotors of this instrument, each carrying its appropriate timbre-forms;

Fig. 2, an elevation of a rotor equipped with its timbre-forms, showing also, more or less diagrammatically, a partial-mixing system together with grading, enlarging and translating devices therefor;

Fig. 3, a side face elevation of a timbre-form with associated means for generating electrical pulsations;

Fig. 4, a diagrammatic view of the mechanism for securing a powerful and satisfying bass, also showing in end view, in perspective, a portion of the partial-mixing system;

Fig. 5, a detail of a horn reproducer and a portion of its associated electrical mechanism;

Fig. 6, an end elevation of one reed of an interrupter unit and its operating mechanism;

Fig. 7, a plan view of a like-note unit of an interrupter system for producing electrical pulsations showing the several reeds of the unit and associated parts, adapted to produce an especially powerful bass and true and satisfying treble.

Referring first to Fig. 1, the twelve timbre-form-carrying cylinders designated on the drawing C rotor, C# rotor, D rotor, D# rotor, and so on throughout the octave to and including the B rotor at the top, are driven by a motor 1 of any suitable type, energized by a suitable current-source 2. The motor 1 is geared to the lower or C-rotor cylinder by gears 3 and 4, so that this cylinder shall, in operation, revolve at a speed per second which is half that of the vibrational frequency per second of the lowest note C of the instrument, a speed which obviously causes the two-toothed timbre-form to generate the correct number of vibrations per second to produce the lowest note C of the instrument. The four-toothed timbre-form will then generate the octave or second note C, and the eight, sixteen, thirty-two, sixty-four, and one hundred and twenty-eight toothed timbre-forms the remaining notes C of a seven octave instrument in their respective order, thus providing for the primes or first partials of all of the notes C of the instrument.

In Fig. 1 the number of vibrations producing each prime of the C-rotor is indicated below said rotor, as C 32.33, C# 64.66, C 129.33, etc., while the other numerals indicate the number of teeth or crests of the timbre-forms for each partial including the first partials or primes. In Fig. 2 the primes for the C-rotor are indicated on the left-hand side of said rotor, the numerals on the right-hand side of said rotor indicating the number of teeth or crests of the timbre-forms which produce the five other partials accompanying each prime up to the last two. As the second partial of a tone has twice the number of vibrations of its prime; the third partial three times that of its prime; the fourth, four times; the fifth, five times; and the sixth, six times, it will be observed that the timbre-forms accompanying any prime have tooth-numbers in the same relation. By this arrangement the highest prime necessary for all ordinary instruments is produced from a timbre-form having one hundred and twenty-eight teeth or crests, and as there is little if any musical significance above a pitch of about four thousand vibrations per second, I have found it quite practicable to drop out partials when they pass above this range. For this reason the fundamental timbre-form having sixty-four teeth carries but three additional partials, while the fundamental timbre-form having one hundred and twenty-eight teeth carries but one additional partial, viz, its octave, produced from a timbre-form having two hundred and fifty-six teeth.

The words "teeth", "toothed", etc., are here employed for want of better terms, to indicate that the periphery of each timbre-form has alternate elevations and depressions, or a substantially sinusoidal outline. The elevations and depressions are preferably of curved form throughout, or in other words, truly sinusoidal, but may approach or attain an angular form without departing from the spirit of the invention or rendering unsuitable the vibrations incident to such sinusoidal outline. The true sinusoidal form, however, is preferably used in practice, because a true undulatory current is thereby ensured instead of one more or less abrupt in its changes.

Since each of the twelve rotors illustrated in Fig. 1 carries identical timbre-forms, it is obvious that they must be speeded relative to each other in the relation of the vibrational frequencies of the notes of the musical octave in equal temperament. That is to say, in order to have the C-rotor produce the notes C and the next rotor above produce the notes C# of the tempered scale, the C-rotor, as shown, must drive the C# rotor at a speed represented by its own speed multiplied by the twelfth root of two, (that is 1.05946+) and the same ratio obtains, of course, between any rotor on the drawing and that next above it. As clearly set forth in the patent to Thomas, No. 1,156,329, already referred to, this result is approximated with remarkable and quite sufficient closeness by the use of gears having 196 teeth driving into gears of 185 teeth. I equip my C-rotor, therefore, with a gear, as 4, having 196 teeth, and my C# rotor with a gear, as 5, having 185 teeth, with which the gear 4 meshes. The C# rotor is also furnished with another gear, as 6, having 196 teeth to mesh with a gear 7 on the D-rotor having 185 teeth. The D-rotor is likewise provided with a 196-toothed gear 8 which meshes with the 185-toothed gear 9 on the D# rotor, and so on

to and including the B-rotor which, of course, needs only the 185-toothed gear since it drives no other rotor.

Where the instrument is to be played with other instruments it is essential that its pitch shall remain sensibly constant, and in the more complete embodiments of my invention I contemplate using synchronizing mechanism such as shown and described in U. S. Patent No. 1,186,851 issued to me June 13, 1916, or some equivalent means. This mechanism is not, however, illustrated or described in the present application, since it is clearly set forth in the patent noted, and is obviously within the province of my invention.

Referring now to Fig. 2, 10 indicates the driving shaft of the C-rotor of Fig. 1, and 11 the rings of nonmagnetic material which serve to separate and properly space all the timbre-forms 12. To the right of the rotor illustrated in Fig. 2 and extending vertically throughout its length, is a series of circles diagrammatically representing flux-producing magnets like those seen in Fig. 3, and each coacting with the timbre-form opposite which it is placed. The first six of said magnets are, for descriptive purposes numbered 13, 14, 15, 16, 17 and 18 respectively, and each is provided with a permanently magnetized core so that whenever a timbre-form 12 of magnetic material revolves in proximity to one of said magnets, electrical pulsations are set up in its surrounding coil and are translated into sound, provided the other factors of the instrument conspire to that end. It will be noted that all these magnets are in parallel on one side, being served by the common wire 19 running to one pole of the primary 20 of an induction coil whose secondary 21 is connected with electrical enlarging means of any suitable type, that shown being of the vacuum-tube type familiar in radio practice.

As previously explained, the rotor shown in Fig. 2 carries but seven primes or fundamentals, the fundamental for the lowest note C of the instrument being produced by the timbre-form having two teeth, while the five other partials of this note are respectively produced by the succeeding timbre forms having four, six, eight, ten and twelve teeth or crests, all six of said partials, when used together as shown, constituting a tone of composite timbre but of one musical pitch, to wit, that of the note C of 32.33 pulsations per second. The mechanism by which the desired upper partials of this C-prime are selected and graded and added to the fundamental, is shown at the upper right-hand side of Fig. 2. This is a side view of the essential parts of what is known as the partial-mixing system, and is here shown with two gradations of power for each partial. It is to be understood, however, that more could, and often will, be used, but to multiply them in this showing would be an unnecessary reduplication of parts. It will be noted that one lead wire from magnet 13 is divided into two branches 13^a and 13^b, and that in the branch 13^b there is inserted a resistance or impedance, suitably to reduce the strength of the pulsations of magnet 13. The corresponding leads of magnets 14, 15, 16, 17 and 18 are similarly branched, but in each of these branches there is a resistance or impedance which, in the case of magnet 14, is designated 14^a for the lower degree of resistance and 14^b for the higher degree, so that if the circuit is completed through branch 14^a the pulsations will be stronger than if it is completed through branch 14^b. The arrangement is identical as to the other magnets of the group except that the values of

the resistances or impedances will probably be different in the case of the different partials, since as a general rule the higher partials are weakest. There are, however, occasional exceptions to this rule. As the prime of any note is often, indeed, commonly, used without a resistance so far as the partial-mixing system is concerned, one of the branches from such prime, as 13^a, is shown devoid of resistance or impedance, so that a prime of maximum strength may be obtained when desired. The other partials are commonly not wanted in full strength, and are, therefore, each shown in two degrees of lesser strength.

Magnetically controlled rockers 13', 13'' carry contact fingers adapted to co-act with contacts carried by the branches of the lead wire from magnet 13, the contact fingers carried by rocker 13' co-acting with the contact of branch 13^a, and the contact finger carried by rocker 13'' co-acting with the branch 13^b. Similarly, the contact finger carried by rocker 14' co-acts with the contact of branch 14^a, the contact finger carried by rocker 14'' with the contact of branch 14^b, and so on in like manner throughout the remainder of the twelve contacts serving this one note C of 32.33 vibrations per second. Each of these twelve rockers is actuated by a magnet indicated by *a* or *b* as marking the degree of intensity with which it is associated, followed by the number of its partial. For example, the uppermost magnet is designated *a*¹ because it operates the rocker serving to produce the strongest possible first partial or prime; the second magnet operating the rocker next below it is designated *b*¹ because it interposes a resistance or impedance in the line from the first partial, and so on, the last magnet being designated *b*⁶ and operating the rocker which brings into action the weaker intensity of the sixth partial.

In Fig. 2 the twelve rocker points are shown co-acting with the twelve magnet-lead-points associated with the note C of 32.33 vibrations, but upon inspection of Fig. 4 which shows a portion of this same partial-mixing system in perspective, it will be seen that the rocker 13' carries many other co-acting points behind the one shown in Fig. 2. In fact, there is one such rocker-point for every prime in the instrument without resistance, or eighty-four in all counting that appearing in Fig. 2. Similarly, rocker 13'' carries eighty-four co-acting points insulated from each other, and so on throughout the remaining rockers, except that as the prime becomes higher and higher in pitch, some of its higher partials will pass beyond the range which can be reached from a two hundred and fifty-six toothed timbre form. In such case they are omitted until, when the prime resulting from the timbre-form of one hundred and twenty-eight teeth is reached, only the second partial is retained, and all of the corresponding tongues on the rockers representing higher partials are omitted.

The rocker tongues shown in Fig. 2 are all associated with the lowest note C of the instrument, and from each of them extends a wire 22 connected with a wire 23 common to all the partials of this note C. The wire 23 leads to the upper member 24 of a contact switch beneath the lowest note C of the key-manual, as indicated by the dotted line 25 leading to the rear end of said key. This switch mechanism is shown more in detail just beneath the portion of the manual illustrated. Here 26 indicates the key, 27 a regulating screw for the pressure member 28, 150

and 29 the lower of the co-acting contact springs to which is connected a wire 30 leading to a brush 31 traversing the appropriate C-32.33 section of the expression-control 32 operated by a pedal or other means 33 against a retracting spring 34. A brush 35 bears upon a lower conducting segmental portion of expression-control 32, and to this conducting portion are wired the left-hand ends of all the resistance or impedance sections of said expression-control, which are to be associated with the enlarging tube 36 and translating diaphragm and horn 37, the brush 35 being joined by a wire 38 to one pole of the primary 20 of the induction coil for said enlarging means.

It is obvious, therefore, that if the lowest C-key of the manual be pressed, the periodicity and the strength of the partials delivered to brush 31 will be determined by the rockers of the partial-mixing system which are then in contact, and this, in turn, will be determined by such of the rocker-actuating magnets a^1 , b^1 , a^2 , b^2 , a^3 , b^3 , etc., as may be energized. A wire 39 common to one pole of each of the twelve rocker-actuating magnets, is joined to a current-source 40, from the other pole of which a wire 41 connects with tappet return-contacts 42, 43. When bridging switch 44 is depressed as shown, the tappet contact 45 co-acts electrically with contact 42 through the medium of a wire 46 leading to the uppermost of the rocker-actuating magnets the circuit being completed through the common wire 39. This establishes the circuit of said magnet, causing the full strength of the prime of C-32.33 vibrations to be delivered to brush 31 upon depression of the lowest C-key of the manual. Suppose, now, that instead of depressing switch 44, the switch 47 be operated to electrically unite contact 43 with contacts 48, 49 and 50. From these three contacts wires 51, 52 and 53 in the order named, run to rocker-actuating magnets a^3 , b^3 and a^1 , so that upon depression of the lowest C-key of the manual, a full prime, the strongest third partial obtainable from the action of one rocker, and the weakest available fifth partial, will be delivered to brush 31.

To avoid confusion it must constantly be borne in mind that under this last explained tappet condition, not merely the note C of 32.33 vibrations, but every note played on the manual save only a few of the highest, will be given these partials in their relative strengths. Should it be desirable, for example, to have a third partial stronger than above described, this can be obtained by merely energizing both rocker-actuating magnets a^3 and b^3 associated with the third partial. In such case both third-partial rockers 15' and 15'' will be actuated, and current will flow in parallel through each resistance in the branches 15^a and 15^b which are shown in Fig. 2 as connected with the permanent magnet 15 opposing the six-toothed timbre-form. In order to avoid complicating the showing I have illustrated only the two tonal colors just described, but it is to be understood that there would ordinarily be a great many more timbres in an instrument, each with its appropriate tappet mechanism for the instant energization, at the will of the player, of any desired number and selection of rocker-actuating magnets. It must also be remembered that each partial may have as many degrees of strength as may be desired, without in the least departing from the principles of the invention as herein shown.

For the sake of simplicity I have shown the tappet system more or less conventionally, since it is so well known in the art that complicated detailed accuracy is quite unnecessary. The current-regulating expression-control means 32 may be any of the suitable well-known forms, but is here shown somewhat conventionally in Fig. 2 as consisting of groups of soft iron wires wound with current-carrying wire adapted to be traversed by individual brushes, each such group being bent for that purpose into the arc of a circle, and there being one such group for each note of the instrument. 54 indicates a wire connecting the ends of the current-regulating groups to a cylindrical segment 55 of conducting material, and as many notes are wired to this one segment as are to be associated with a single enlarging unit and translating means, as already set forth. In my companion application, Serial No. 329,647, (now Patent No. 1,893,250), I show at Fig. 8 thereof a more detailed drawing of this current-control mechanism, in which the brushes traverse insulated segmental contacts similar to those shown in Fig. 4 hereof, said contacts being connected to resistance or impedance members in the usual way.

As stated, the enlarging means used may be of any convenient type, and I have shown conventionally a type sometimes used in radio work. Here, as already described, the secondary coil 21 picks up the pulsations in the primary 20, passing them to the enlarging tube 36 and primary coil 56, from which they are picked up by the secondary coil 57 and converted by the magnet 58 and diaphragm and horn 37 into sonorous vibrations of the correct timbre and loudness for musical rendition. Any suitable enlarging means may be used, and for this reason I have not considered it necessary to describe in detail that which I have conventionally shown. I have shown in connection with the rotor cylinder of Fig. 2 the wiring and connections of but one note and its partials, to wit, the lowest note C of the instrument. It will be readily understood, however, that the arrangement is precisely the same with the next note C of 64.66 vibrations and its partials, except that the manual note is farther up the scale, the timbre-forms lower on the rotor cylinder and slightly different as to teeth, and the partial fingers, pedal sections, etc., the appropriate distance away from those shown in Fig. 2.

Referring now to Fig. 3, 59 indicates a four-toothed timbre-form mounted on a cylindrical rotor 60, while the numerals 61, 62 and 63 indicate identical permanent magnets surrounded by a helix of wire and adapted, when the timbre-form 59 is revolved in proximity to them, to generate pulsations in their helixes dependent in character upon the formation of the timbre-form and its speed of rotation. 61^a indicates one of the magnetized cores of said magnets, and is shown as presenting a surface to the timbre-form narrowed along the plane of the axis of said timbre-form, for the purpose of attaining better and truer articulation in its pick-up. 64 indicates a similarly narrowed and magnetized core attached to a microphone capsule 65, so that, as the rotor 60 and timbre-form 59 are revolved, the change in the magnetic air-gap enables the microphone to operate as a pick-up in a manner well-known in the arts. 66 indicates a source of current for operating the microphone 65, one pole of said source being connected to the microphone and the other to the primary 67

of an induction coil. When the switch 68, 68^a is operated through depression of a key of the manual, an adjustable rheostat 69 is brought into circuit with the other pole of current-source 66 and with microphone 65, thus completing the microphone circuit. The rheostat 69 regulates the strength of the current energizing the microphone. A secondary coil 70 co-acts with the primary 67, and its leads may be connected with any suitable enlarging means (not shown in Fig. 3) either singly or in any desired grouping. 71 indicates a translating device of conventional type, suitable for converting into sonorous vibrations the electrical undulations of any number of grouped timbre-forms.

Referring now to Fig. 4, three of the partial-mixing rockers shown in side view in Fig. 2 are here seen in perspective, the magnets for operating the same being indicated at 72, 73 and 74. 75 indicates a tappet switch which serves when depressed, to energize all three of the magnets shown. 76 indicates a source of electrical energy, one pole of which is connected to the tappet-finger 77, and the other pole of which is connected by a common wire 78 with one pole of each of the magnets 72, 73 and 74. The other poles of said magnets are connected by wires 79, 80 and 81 with tappet fingers 82, 83 and 84, so that upon depression of the tappet switch 75 into the position shown, all three of the rocker-actuating magnets are energized and their associated rockers brought into active position as shown. The uppermost rocker of this figure corresponds to rocker 13' of Fig. 2, and its depression will bring into action the primes, fundamentals or first partials in their full intensity; the middle rocker corresponds to rocker 14' of Fig. 2 and its depression will bring into action the *a*-intensity of the second partials; while the third rocker corresponds to the rocker 15'' of Fig. 2 and its depression will bring into action with lesser intensity the third partial. 85, 86 and 87 indicate respectively portions of the C, the C# and the D timbre-form-bearing cylinders, each shown with four pulse-generating permanent magnets 88, 88^a, 88^b, 88^c, opposed to the four timbre-forms at the left-hand end of each cylinder, which in this case is its lowest or base end. The four magnets opposed to the C-rotor 85 are designed to generate respectively the prime C-32.33 and its second, third and fourth partials, only the first three partials being wired in the drawing. Similarly, the C#-rotor 86 is shown opposed by four magnets intended to generate the first four partials of the lowest note C# of the instrument, and here again only three of said partials are shown wired for use in the timbre designated. In like manner the upper or D-rotor 87 is opposed by four magnets designed to generate the first four partials of the lowest note D of the instrument, three only being wired for use in the timbre illustrated. The three wired magnets 88^a, 88^b, 88^c of the C-rotor 85 are joined by one of their poles to a common wire 89 connected to one terminal of the primary 90, and in like manner one pole of each of the magnets 88^a, 88^b, 88^c of the C#-rotor 86 is joined to a common wire 91 connected to one terminal of the primary 92 of an induction coil, while the magnets 88^a, 88^b, 88^c of the D-rotor 87 have each one pole joined to a common wire 93 connected to one pole of the primary 94 of an induction coil. It will be noted that I have shown a separate induction coil for the C-rotor, another for the C#-rotor, and a third for the D-rotor. The reason for this is

that these are all notes of the first or lowest octave of the instrument and are designed to have each its resonant pipe 95, 96, 97 in the order of the scale, as will be presently explained.

Considering now the other poles of the three wired magnets 88^a, 88^b, 88^c opposed to the timbre-forms of each of the three rotors 85, 86 and 87, it will be noted that they are connected by individual wires as follows: The magnet 88^a of each rotor has its individual pole connected respectively by wires 98, 99 and 100 with the left ends of the first, second and third pairs of co-acting tongues 101, 102 and 103 of the rocker 13'. In a similar manner the magnet 88^b of each rotor has its individual pole connected by a separate wire 104, 105 and 106 and joined in the order mentioned to the left ends of the first, second and third pairs of co-acting tongues 107, 108 and 109 of the rocker 14' of Fig. 4. The magnet 88^c of each rotor has its individual pole connected by a separate wire 110, 111 and 112 respectively to the left ends of the first, second and third pairs of co-acting tongues 113, 114 and 115 of the rocker 15'' of Fig. 4. The other ends of each of the first or nearest pairs of co-acting tongues 101, 107 and 113 are joined by wires 116 with a common wire 117 leading to the lower contact of the key-switch 118 actuated by the C-key of the lowest octave of the manual. In precisely the same manner the other ends of the second or middle pairs of co-acting tongues 102, 108 and 114 are joined by wires 119 to a common wire 120 leading to the lower member of a switch 121 actuated by the second or C#-key of the same octave on the manual. In the same way the other ends of the third pairs of co-acting tongues 103, 109 and 115 are joined by wires 122, 123 and 124 with a common wire 125 leading to the lower contact 126 of the key-switch actuated by the third or D-key of the lowest octave of the manual. The upper contacts 118^a, 121^a and 126^a of these three key-switches are each wired as follows: The contact 118^a below the C-key of the manual to an expression-control brush 127; the contact 121^a below the C#-key of the manual to a similar brush 128; and the contact 126^a below the D-key to the brush 129. 130 indicates a cylindrical rheostat or impedance member, operated by a pedal 130^a or equivalent means. The first twelve sections of this expression-control are of smaller diameter than the succeeding sections, and are associated with the lowest octave of the instrument, the notes of which are each provided, as shown, with a separate enlarging means 131 and with the separate means 95, 96, 97 as indicated for the first three notes, for translating the electrical waves into sonorous vibrations with a satisfying amount of volume and a sufficiency of power. This expression-control 130, like the expression-control 32 in Fig. 2, may be any suitable means for controlling at will and for the purposes of musical expression, the energy of the current flowing through it. In the device shown in Fig. 4, contact blocks traversed by brushes are connected to resistances or impedances in the familiar manner for such purposes. In the case of the left-hand portion of the expression-control as viewed in Fig. 4, which is associated with the lowest octave of the instrument, each of the twelve sections 132, 133, 134, etc., together with its feed and its collector brush, is electrically insulated throughout from all other sections and brushes. This is necessary because each note is provided with its own individual sound-generating pipe or horn.

Considering now the section of the expression-control 130, of larger diameter, the three upper brushes 135, 136 and 137 constitute, in this case, portions of the circuits connected with the first, second and third notes of the second octave of the instrument. Below these three brushes and co-acting with them as a collector brush, is a brush 138 connected by a wire 139 to one pole of the primary 140 of an induction coil whose secondary 141 feeds an enlarging system. This enlarging means is not shown connected with the induction coil 140—141 in Fig. 4, but said induction coil being the functional equivalent of secondary coil 90^a, it feeds an enlarging system (not shown) which in turn energizes the primary coil 142, secondary coil 143 and sonorous member 144 shown in Fig. 5.

As above explained, each section of the expression-control 130 of larger diameter is traversed by an upper brush such as 135, 136, 137, individual thereto, while the portion traversed by the collector brush 138 is common to one end of all the upper sections opposite it to just the extent that these upper sections serve the one enlarging means. The sections of expression-control 130 of smaller diameter each have an individual continuous conducting section throughout the portion co-acting with the lower brushes 127^a, 128^a, 129^a, etc., and this conducting section is in each case wired to one end of its associated co-acting graded impedance or resistance sections, in the manner familiar in such cases. This arrangement is used because each note of the lowest octave, as stated, has its own individual enlarging means such as 95, 96, 97, etc., and its individual sound-generating means. I have shown this mechanism in connection with the first or lowest octave only, that being the octave where the greatest volume is desirable. It is obvious, however, that where expense is not a vital factor, this arrangement may well be continued another octave or more.

Only one enlargement for the actuating power of each of the bass units 95, 96, 97, etc., Fig. 4, is here illustrated, but it is perfectly obvious that further power-enlargement may be used wherever desired, and it should be understood that the invention is not confined to the single enlargement shown. Moreover, the invention is not limited to the particular means shown for generating the pulses used in the actuating magnets of the bass sounders 95, 96, 97, or their equivalents, any of the well-known means for creating strong and accurately-timed pulsations being well within the scope of this invention. One such means consists in supplying said actuating magnets with direct current rendered pulsatory through the agency of revolving, timed commutators and contacting brushes. Such a commutator might conveniently replace the extreme leftward ring on each of the twelve rotors shown in Fig. 1. Any means, however, which, in an instrument using electrical enlargement and its well known sonorous translation for its treble sections, will permit, in its low bass, the efficient vibration of the great masses of air necessary in order that these tones may properly support, and not be buried by, the instrument's treble, comes well within the province of the invention and is to be understood as so claimed by me.

This matter of increased volume is one of the very important objects of my invention, and while its attainment is of paramount importance for the low bass, no satisfying bass being producible without it, material augmentation of volume.

even in the treble sections of an instrument of this type, is greatly to be desired. In radio practice, and in phonographic reproduction, much difficulty is encountered with low-pitched tones, because there seems to be no known way of making loudness do duty for volume. In the case of musical instruments of the type herein set forth, I achieve the desired results by means adapted to vibrate a sufficient quantity of air to give a more satisfying sense of volume. Furthermore, I have found by much experience that there is a decided musical advantage gained by having as wide a diversity of sounding members as is practicable, instead of just one or a very few. The mere distribution of the pieces of an orchestra over a considerable area, instead of having the tones of all the speaking instruments come to the listening ear as if through one small hole, is a most important musical gain of which I take all practicable advantage.

There is, however, still another vital consideration. Diaphragms, or their sonorous equivalents, are the common means of translating electrical pulsations into sound waves, and it needs scarcely to be mentioned that such translation is accompanied with distortions unavoidable in the present state of the art. These diaphragms have their favorite pitches at which they shriek, as it were, and their occasional antagonisms at which it is difficult to make them give any satisfactory speech. Moreover, they simply will not give any good musical results below the pitch of their natural fundamental, and the same is true of all like resonators. These diaphragms, or equivalents, are produced from relatively stiff plates which have to bend in functioning, and to produce ideally perfect results they should be able to bend at a mathematical line. Naturally, they can never do this, the result being that the relations subsisting between simultaneously sounded partials are falsified in some degree and the musical results impaired. A similar phenomenon occurs in strings, particularly metal strings, whose nodes cannot be made to confine themselves to a mathematical point, but spread somewhat along the string on each side of such true node, thus shortening the ventral segments. These difficulties, which are inherent in diaphragms, strings, etc., cannot be completely eradicated by any means at present known, but they can be so greatly lessened as to approach negligibility, a result that I accomplish by the improved means herein described.

The large pipes 95, 96 and 97 are employed to move the large volume of air properly associated with tones of the low pitches which they are intended to elicit. I do not, however, confine myself to this particular way of moving a large volume of air, as a sound-board or any other suitable means of setting a large mass of air into vibration may be used. Moreover, the means for moving the requisite large volume of air for the low pitches need not be individual to each note, since if a sound-board were employed, it might respond to a plurality of notes.

Having already adverted to the base, I will now consider more particularly what may be done to beautify the treble. The ideal thing would be to have a separate enlarging means, diaphragm and resonator for each note of the treble referred to, but this would ordinarily be prohibitive in its expense. Accordingly, I make use of one of two broadly alternative expedients, which I will describe in their order. First, I connect similar notes of said treble (I may even include the bass

though I prefer not to for reasons given unless economy demand it), as for example all the C-notes, to one sound-generating means, thus having in all six resonators exclusive of the bass. An

5 advantage of this arrangement is that the diaphragm, or equivalent device used, may be tuned to favor these particular pitches and so rendered of truer and more efficient speech. Second, I connect the notes of the gamut in serial groups as, 10 for example, the second octave in one group, the third in the next and so on, each group having its individual enlarging means and sound-wave generator. This arrangement does not possess the advantage of tuning the translating means with 15 particular notes of the musical octave, but it has a rather more important advantage in that the size and thickness of the diaphragm and associated resonator may be chosen with reference to a much narrower range of pitch, thus permitting 20 the diaphragm thickness to be increased, its diameter decreased, and the volume-effect of its resonator lessened as the pitch rises. Each of these means offers the advantages of satisfying volume, diversity of location, greatly improved 25 speech and quality, and far greater carrying power without appreciable distortion, and both are quite within the province of my invention as herein set forth.

Figs. 6 and 7 show means for producing correctly timed and shaped electrical waves for use in a musical instrument of the type set forth, together with parts necessary to the explanation of such use. Referring first to Fig. 6, 145 designates one of the reeds of the reed-unit seen in 30 Fig. 7; 146 the non-magnetic metallic block upon which said reed is mounted; and 147 the magnet for vibrating the reed 145 and interrupting the current for the other six reeds of its group or unit which are in octave relations to said reed 35 145. 148 designates a silver-tipped, somewhat elastic contact-member which co-acts with an adjustable silver-tipped screw 149 for the purpose of alternately making and breaking the circuit in the reed-vibrating magnet 147. 150 indicates a source of electrical energy and 151 the 40 movable finger of an electrical switch, the point of said finger being shown as resting upon the conducting section 152 of the co-acting portion of the switch, the blackened sections on either 45 side denoting insulation. The action of the mechanism is well-known and obvious. When switch finger 151 is thrown into the position shown in Fig. 6, current flows from the battery or other source 150 through the switch and wire 50 153 to the co-acting contacts 148, 149; thence through reed 145 and the metallic block 146 upon which it is mounted, to magnet 147; through said magnet and wire 154 back to the other pole of the battery source 150, thus completing the circuit and energizing magnet 147. The energiza- 55 tion of magnet 147 causes it to attract reed 145 and so open the contact points 148, 149, thus de-energizing said magnet and allowing the reed to spring back to repeat the cycle after the well-known manner in such cases. The opening of 60 contacts 148, 149 being in rhythm with the vibration of reed 145 and that of the other reeds of its unit sustaining octave relations with said reed, it follows that this lowest reed of the unit may be used to interrupt the operating current for all 65 the higher reeds in the same unit. By this method of operation reed 145 will be attracted to magnet 147 every time said magnet is energized, while the next reed in the same unit which 70 is the reed controlling the octave (see 145^b, Fig.

7) will be attracted by its operating magnet on every other swing of said reed toward said magnet. The next reed 145^c (Fig. 7) will be attracted toward its energizing magnet on every 80 fourth swing of said reed, and so on throughout the unit, which comprises all the similar notes of an instrument as, for example, the seven notes C, or the seven notes C# or D, and so on. The free end of reed 145 carries a member 155 preferably of non-magnetic material, and having its 85 outer end bent downward at a right angle to the reed. The tip of this downwardly bent portion is provided with a magnetic member 156 which normally rests somewhat above the center line of the sharpened, magnetized poles of a flux-producing magnet 157. In Fig. 6 the member 156 is 90 shown at approximately its highest position. As reed 145 vibrates, the movement of this small magnetic mass 156 (which is somewhat lozenge shaped in section), is such that the magnetic 95 resistance between the poles of magnet 157 varies in rhythm therewith, thus setting up pulses in the coils of said magnet.

It is distinctly to be understood that I do not 100 confine myself to any particular way of energizing any of the reeds or equivalent devices, since I may use, for example, any of the well-known means to that end which have been employed in 105 multiplex telegraphy and elsewhere. It is also to be understood that the limiting walls or partitions used in the bass sounders 95, 96, 97, 164 and 165 are not to be regarded as "diaphragms" in the sense of those used in telephone and radio 110 practice, or in the sense of that shown in Fig. 5 hereof for use in the treble section of the instrument. The movable partitions or walls shown at the bottom of these bass sounders are preferably 115 rigid disks, ribbed to render them incapable of breaking up into sub-multiple vibrations, said disks being attached in the ends of the pipes by narrow, air-tight rings of leather. This construction permits said disks to move bodily up and down with a plunger-like action, but not to bend telephone-fashion in themselves, and is 120 clearly set forth in my co-pending application, Serial No. 455,876 filed May 26, 1930. This practice not only stops out undesirable partials and keeps the tones simple in quality, but makes for far greater efficiency in the low tones, since the 125 entire partition or plunger has the same amplitude of movement as its center, a very important distinction between my construction and the telephone-type of movable partition or diaphragm. It should be understood, therefore, that these two types of sounders or translators are entirely distinct in kind, the telephone type being designed 130 with a special view to universality of response, while the type used in the instrument of this and the co-pending application mentioned, is designed with equal care to limit it to particularity 135 of response. The claims of this application are accordingly to be interpreted with these distinctions clearly in mind.

Fig. 7 shows a unit of seven reeds 145, 145^b, 145^c, 145^d, etc., the reed 145 being the current-interrupting reed of Fig. 6 just described. Each of the six upper reeds of the unit is actuated by a magnet 158, 159, 160, etc. These magnets are 140 wired in series as shown, one pole of the series being connected to a current source 150^a, and the other pole through a switch 151^a the equivalent of that shown in Fig. 6, and wire 161, to the make-and-break contacts 148^a, 149^a (shown more in detail in Fig. 6), and thence to the metallic reed-bearing frame 146^a, thus completing the circuit. 150

It is to be understood that other reed units identical in principle of construction will be provided, there being, ordinarily, twelve units in all or eighty-four reeds, one for each note of the manual. All these reeds will of course vibrate whenever the instrument is played, though only those associated with the keys pressed will at any time be audible as music.

I have shown in Fig. 7 the manner of controlling as to intensity, for purposes of expression, the electrical pulsations induced by these reeds, as well as the manner in which said pulsations are enlarged and translated into musical sounds. Two enlarging tubes, conventionally shown at 162 and 163, and two resonant pipes 164, 165, are used for this purpose in connection with such a unit of seven reeds. Beneath the free ends of the reeds 145^b, 145^c, 145^d, etc., are shown flux-producing magnets 158^a, 159^a, 160^a, etc., the left-hand pole of each of said magnets being covered by the reed above it. I have likewise omitted for clearness of showing, the right-angled member 155 with its small magnetic mass or tip 156. The seven reeds illustrated in Fig. 7 are all shown as producing primes or fundamentals in either of two degrees of loudness. One of the leads from each of the flux-generating magnets 157, 158^a, 159^a, 160^a, etc., is forked or branched as shown at 145' and 145'', 158' and 158'', 159' and 159'', etc., in a manner similar to that of Fig. 2, each branch 145'', 158'', 159'', etc., carrying a current-reducing impedance or resistance.

Since Fig. 7 shows but one reed-unit with all of its reeds used for primes, the partial rockers 166 and 167 with which each reed is provided are not illustrated in detail. They are, however, the equivalent of the rockers 13', 13'' of Fig. 2 and operate in a similar manner. A common wire 168 joins the upper six pairs of rockers 166 and 167 to one end of a primary 169, the other end of said primary being joined by a wire 170 to the collector brushes 171, 172, 173, 174, 175 and 176 of a sectionally broken expression-control, only the seven C-sections of said expression-control being illustrated. Each of these sections is traversed by another brush 177, 178, 179, 180, 181 and 182 respectively, and is connected through the appropriate manual-key 183 to one pole of its associated flux-generating magnet 158^a, 159^a, 160^a, etc., for such section. Thus depression of any manual-key 183 will complete the circuit controlled by it, energizing primary 169 and secondary 185, the primary 186 being energized through the enlarging means 163. This primary 186 in its turn energizes the secondary 187 and magnet 188 or its equivalent, thus causing the translating device 165 to speak. It will be noted that the lowest pulse-generating magnet 157 is segregated from the other six similar magnets of the unit both as to the wire 189 connected to the partial-rocker mechanism, and as to the wire 190 joined to brush 191 of the expression-control. The other end of wire 190 is connected to the primary 192 of an induction coil, the secondary 193 of which is connected with the enlarging means, 162, said enlarging means causing energization of primary 194 and secondary 195, and through magnet 196 causing the translating device 164 to speak.

Through this arrangement the lowest note of each reed-unit (in this case the lowest note C of the instrument) is provided with an individual enlarging and translating mechanism especially designed and tuned to give the satisfying volume and loudness so necessary to a good bass.

The lowest reed and associated parts of the next unit will be similarly arranged to give the same result when the lowest note C# is played, and so on throughout at least the lowest octave as hereinbefore set forth. There is, however, another method of grouping which I have not illustrated here but which accomplishes measurably well that important feature of my invention which has to do with the attainment of a more satisfying volume and a better tonality. This method consists in providing a plurality of translating devices connected to one enlarging device, either in series or in multiple, each of said translating devices being of as perfect a speech as possible over a particular range, after the general manner of multiple or selective telegraphy. Under this arrangement although some translating devices not best suited to the particular notes speaking at any given time may be constantly sounding as efficiently as they are able at the pitch speaking, there will, however, be one translating device vocal which is especially adapted to notes at or close to that particular pitch. Such translating device, by its better resonance, would tend to dominate the others so far as concerns its own best range, while the others would help greatly to swell the resulting volume, a most important factor in this invention. This method differs from those to which I have already adverted only in that one enlarging means may serve a plurality of translating means, thus affecting an economy as to original cost over the same number of translating means with an individual enlarging means for each thereof. In this way a relatively large number of translating means may be served by a relatively small number of enlarging means with very satisfying results as to volume, etc. However, as this method of grouping is not as economical of power as my preferred type; is of somewhat poorer articulation; and is of perfectly obvious construction in view of what has been shown and explained herein, I am contenting myself with this brief mention of it as a variant of the more fully treated and preferred forms of this invention, within whose scope it so clearly falls.

In my companion application, Serial No. 329,647, I show in Fig. 6 an expression-control operating at the sound-translating device and after the electrical enlargement. In this present invention I prefer to make my gradations for the purposes of musical expression, before the electrical pulsations are enlarged, but I do not wish to confine myself to this method since it is well within the purview of my invention to put this expression-control in any suitable place, and I desire that the claims shall be held as comprehending any suitable order or sequence.

No claim is made herein to any method, structure or apparatus, embodying or employing as an element necessary to its intended functioning, a selenium cell, the equivalent of such cell, or a beam of light.

I claim:—

1. In a musical instrument capable of producing the tones of a musical scale, electromagnetic means including a transformer common to a plurality of partials, for generating a multiplicity of series of electrical waves, each of said series being in periodicity and form suitable to produce one of the partials of one of the notes of the instrument; means instantly available to the player during performance for selecting any one of a plurality of combinations of said partials at predetermined relative intensities; means operable

by the player for grading the power of the electrical waves for purposes of musical expression; means for enlarging the graded waves; and means including a plurality of individualized sound-producing members for converting into sonorous vibrations the electrical waves producing the selected partials, thereby eliciting a tone of any desired timbre.

2. In a musical instrument operable by a key-manual or by automatic roll, means including pulsation-producing magnets each connected to a common wire on one side, for generating a multiplicity of series of electrical waves, each said series being of a form and periodicity suitable to produce one of the partials of one of the notes of the instrument's gamut; means operable by the player for grading the power of said electrical waves for purposes of musical expression; means for enlarging the graded resultant; and means including a plurality of individualized sound-producing members for translating into sonorous vibrations and enlarged waves, and thereby eliciting a tone of any desired timbre.

3. In a musical instrument capable of producing a plurality of timbres, electro-magnetic means set in action by the keys of the manual or their automatic equivalents, for generating a multiplicity of series of electrical waves, each of said series being in periodicity and form suitable to produce one of the partials of the instrument; means instantly operable at the will of the player during performance, for selecting and simultaneously eliciting any desired number of partials, graded as to relative intensities; means for combining the selected partials into a composite resultant, one of said partials serving as a prime and one or more thereof serving as an upper partial or upper partials; means for grading the power of this composite resultant for purposes of musical expression; means for enlarging the graded resultant; and means for converting the same into sonorous vibrations.

4. In a musical instrument provided with electro-magnetic means for the separate production of series of electrical pulsations of periodicities comprehending the periodicity of every partial of every pitch and quality used in the instrument; means, operable at will, for grouping with the pulsations in rhythm with the partials used as primes, other pulsations in rhythm with the partials used as harmonics of said primes, the last-named pulsations in a variety of groupings being selected, at the will of the player, as to periodicity of vibration and relative intensities, in accordance with the timbre desired; means, under control of the player, for varying the power of these composite electrical pulsations for purposes of musical expression; means for enlarging the composite pulsations; and means for converting said pulsations into sonorous vibrations of the same general wave-characteristics.

5. The herein described method of producing musical tones of different pitches and qualities, which consists in electro-magnetically generating a multiplicity of series of electrical pulsations, each said series having the periodicity of some partial necessary to some of said different pitches and qualities; determining at will which partials shall comprise each electrical timbre-equivalent and regulating the relative intensities of such partials; grading the power of these more or less complex timbre-equivalents for purposes of musical

expression; combining a plurality of the graded equivalents to produce the desired composite tone; enlarging the combined pulsations; and converting these combined pulsations into sonorous vibrations of similar form.

6. The herein described method of producing in a musical instrument employing electrical enlarging means, a bass of satisfying quality, volume and proper musical balance as regards its own and the treble section of the instrument, which consists in producing from enlarging and sound-resonant devices each individual to and specially designed for maximum volume, purity of speech and efficiency regarding the one particular pitch with which it is associated, certain of the lower notes of the instrument, and eliciting from suitable enlarging means and a single sound-translating device a plurality of the higher notes of the instrument, each said higher note speaking through an instrumentality specially designed to be resonant to the pitches of the selected notes with which it is associated.

7. The herein described method of securing in a musical instrument employing electrical enlarging means, a bass of satisfying volume, timbre and power, and a treble of true quality and of sufficient volume and loudness, said method consisting in eliciting from individual enlarging and individual sound-translating means, certain of the lower notes of the instrument, and in eliciting from suitable enlarging means and a plurality of sound-translating devices, higher notes of the gamut, all the partials in any single composite tone sounded in the treble portion of the instrument being elicited through the same sound-translating device.

8. In a musical instrument employing electrical generating and enlarging means, a rotatable mechanism including twelve cylinders; timbre-forms carried by the respective cylinders, each timbre-form being adapted to produce electrical pulsations of the periodicities and substantial wave-form of a simple or fundamental tone, the speed of each of said cylinders, in operation, being to that next faster in speed substantially as one is to the twelfth root of two; and instantly operable means under control of the player during performance, for selecting and causing a plurality of said pulsations to speak at a plurality of different intensities, upon the pressure of a single key of the manual.

9. In a musical instrument capable of producing the tones of a musical scale, electromagnetic means for generating a multiplicity of series of electrical waves, each of said series being in periodicity and form suitable to produce one of the partials of one of the notes of the instrument; means instantly operable by the player during performance for selecting for simultaneous use, any desired number of said partials graded as to relative loudness; means for grading the power of all the electrical waves simultaneously used, for purposes of musical expression; means for enlarging the graded waves; and a plurality of means for converting said electrical waves into sonorous vibrations, each said means being in material, design and proportions especially adapted to respond efficiently throughout the pitch range of the notes served thereby, to some particular pitch or pitches of the gamut of the instrument.

MELVIN L. SEVERY.