Nov. 27, 1951 E. M. JONES 2,576,759

METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Filed Sept. 22, 1949 6 Sheets-Sheet 1

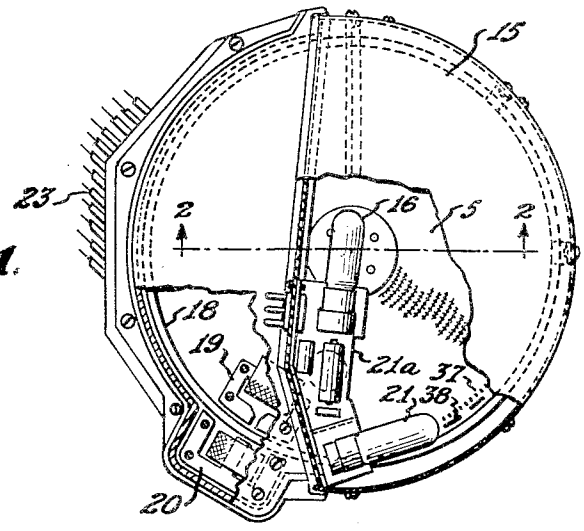


FIG. 1.

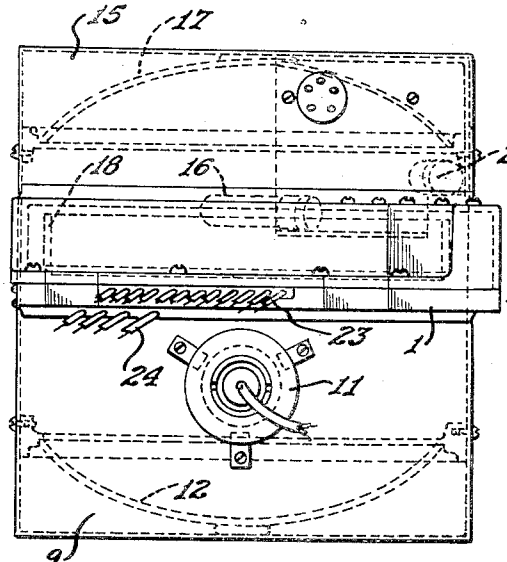


FIG. 3.

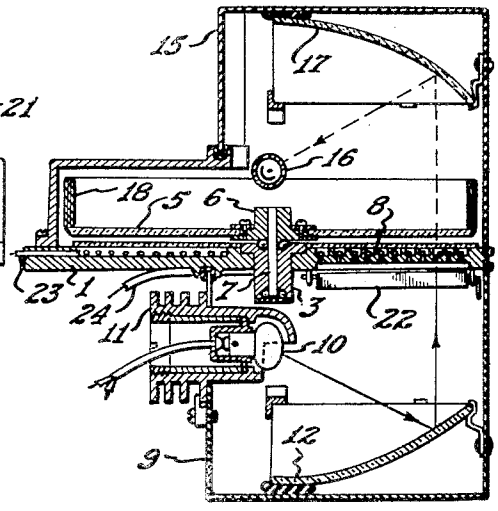


FIG. 2.

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METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Filed Sept. 22, 1949

6 Sheets-Sheet 2

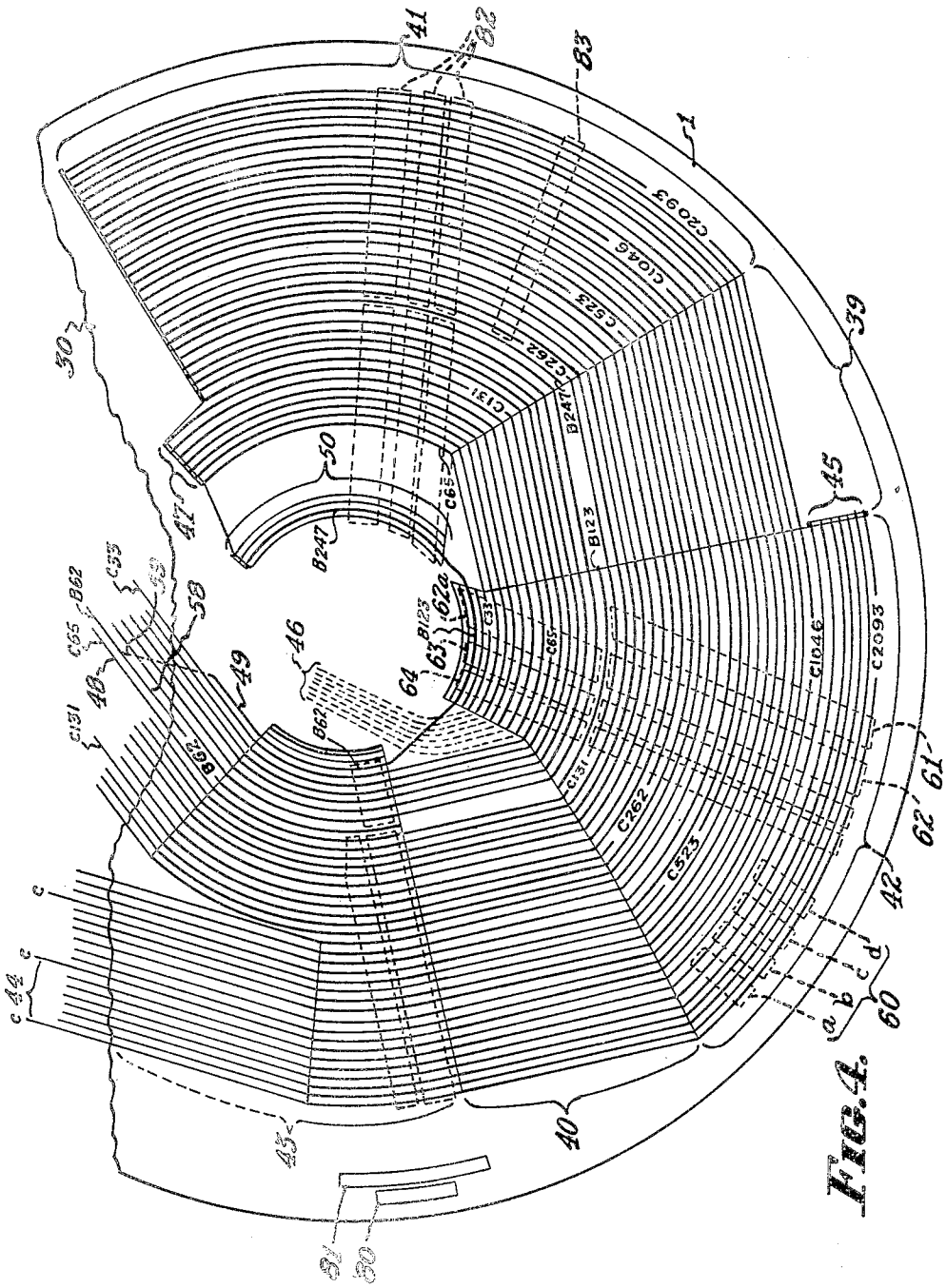


FIG. 1.

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METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Filed Sept. 22, 1949 6 Sheets-Sheet 3

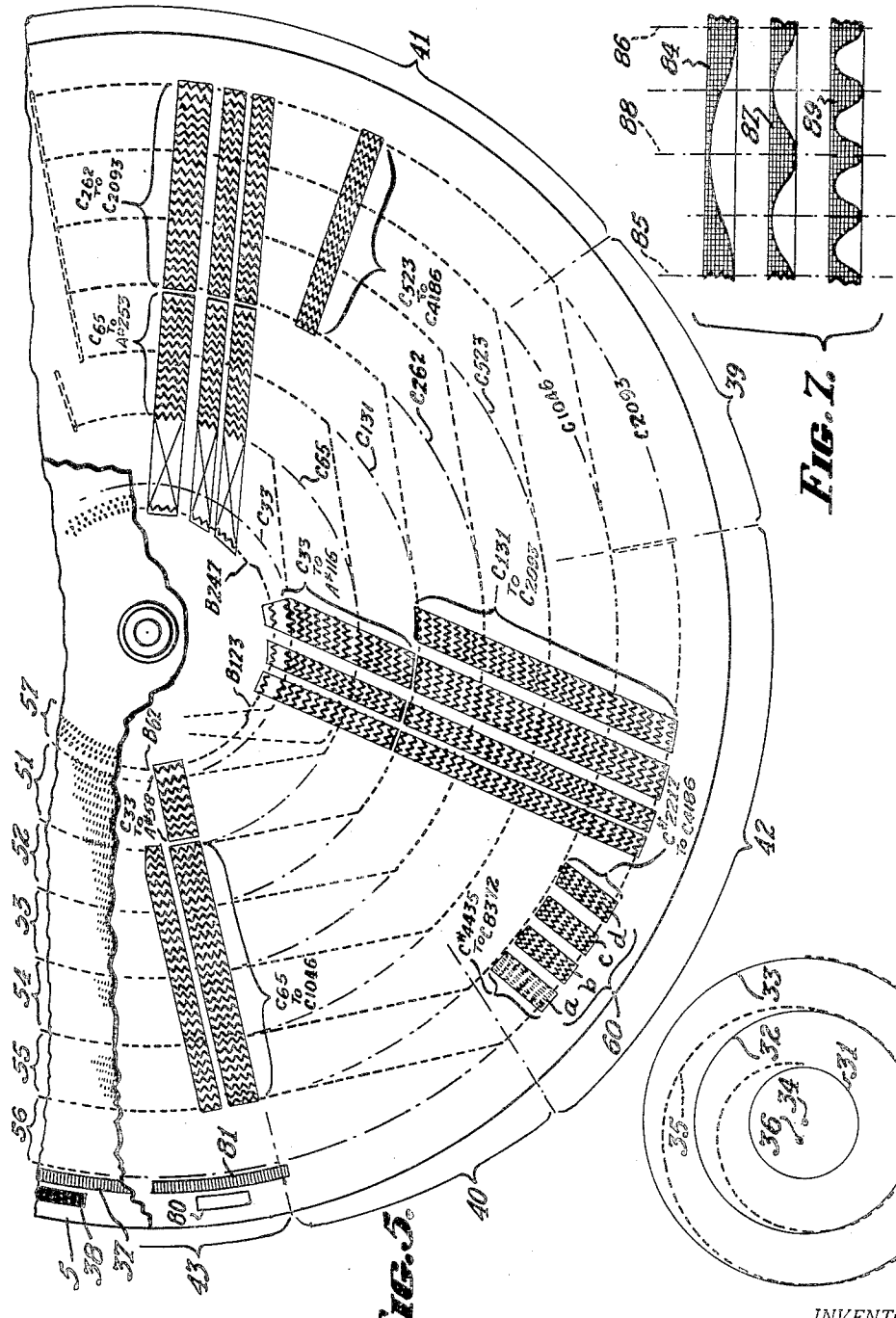


Fig. 5.

Fig. 7.

Fig. 6.

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Filed Sept. 22, 1949

6 Sheets-Sheet 4

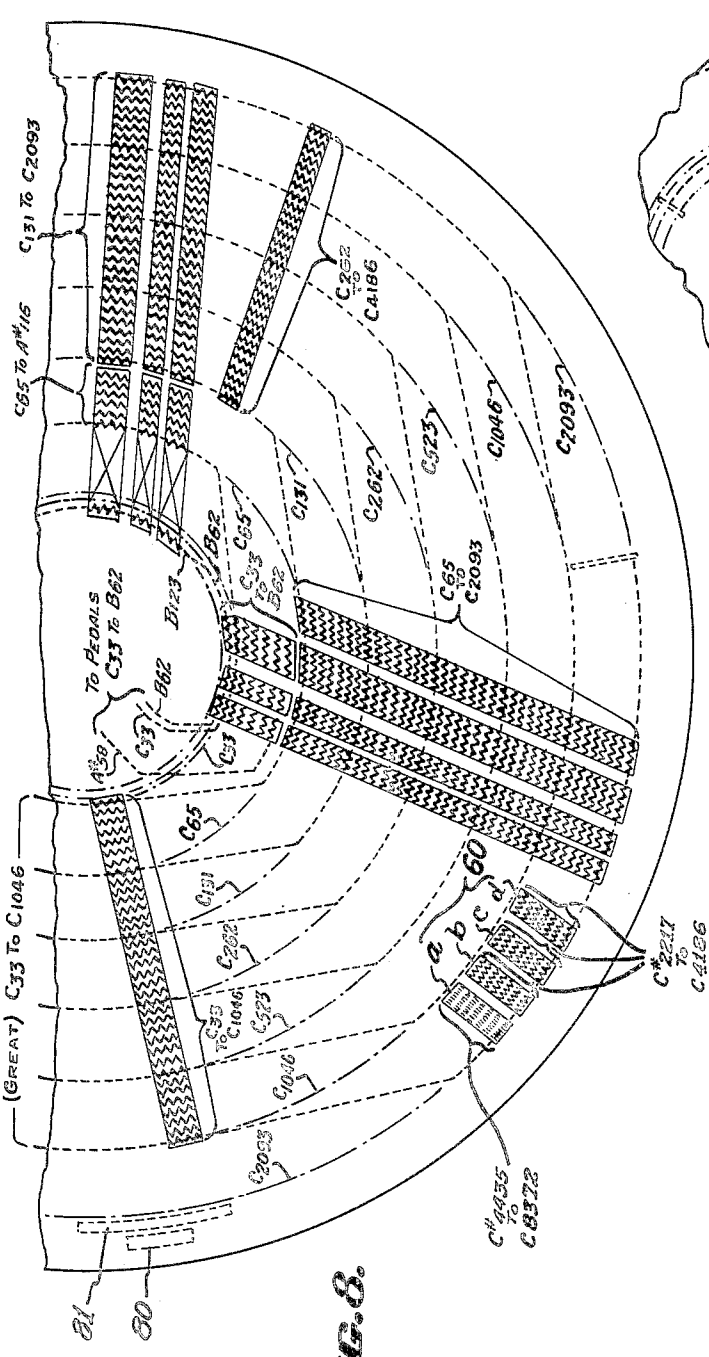


Fig. 8.

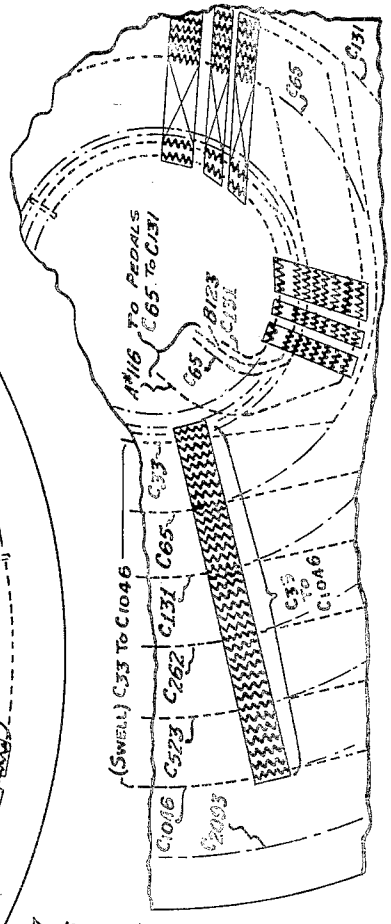


Fig. 9.

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METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Filed Sept. 22, 1949 6 Sheets-Sheet 5

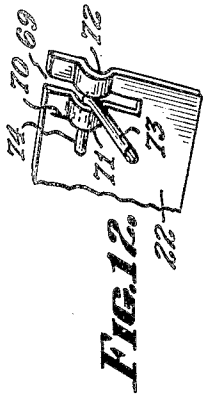


FIG. 12.

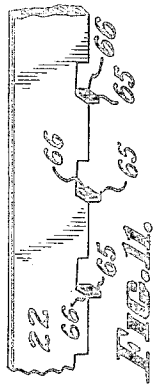


FIG. 11.

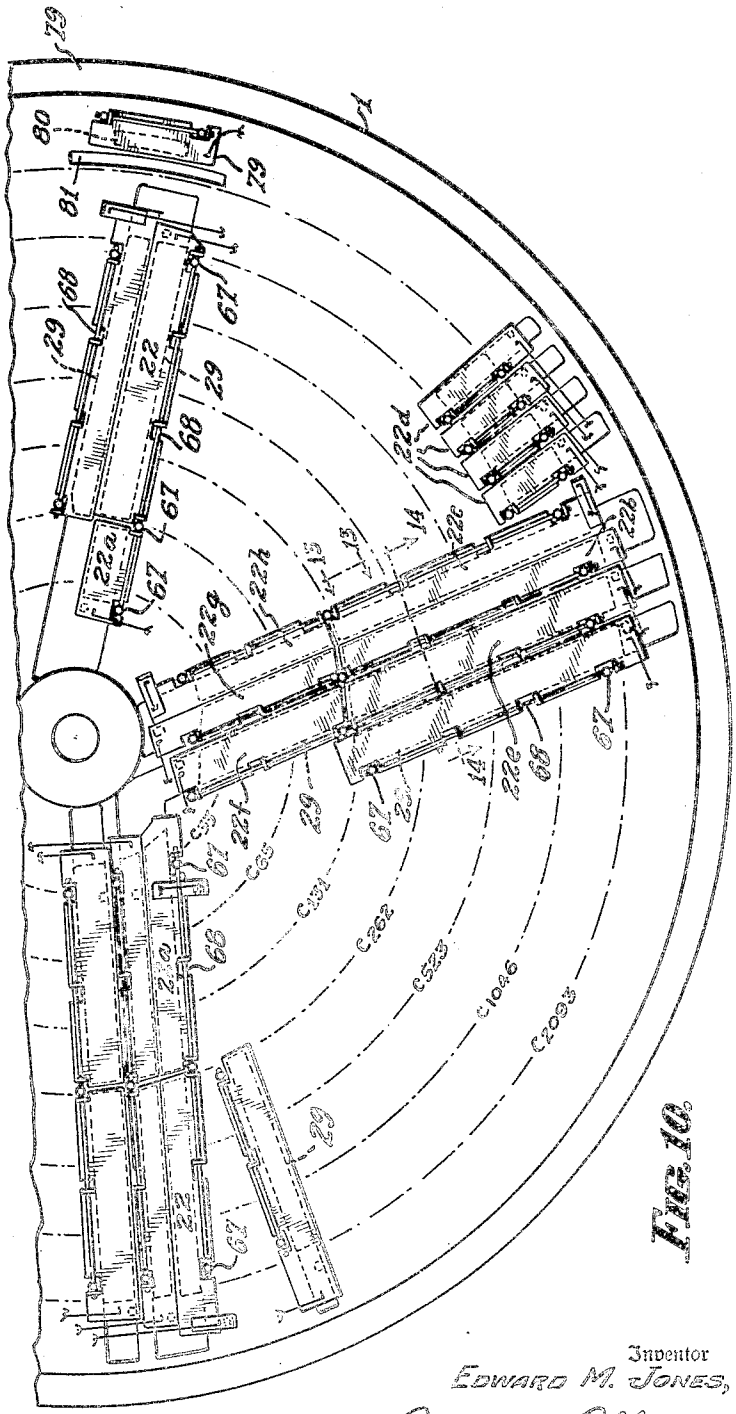


FIG. 10.

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Nov. 27, 1951 E. M. JONES 2,576,759

METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Filed Sept. 22, 1949 6 Sheets-Sheet 6

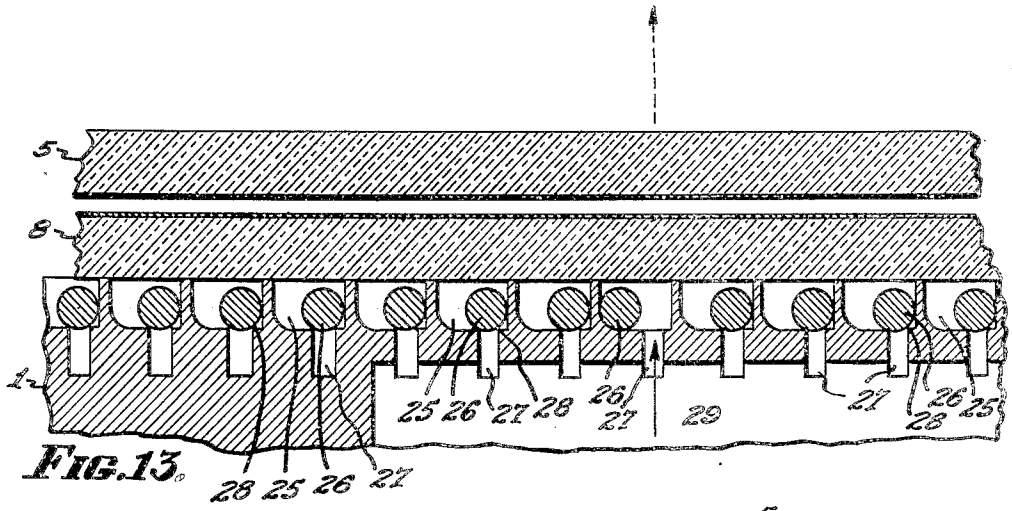


FIG. 13.

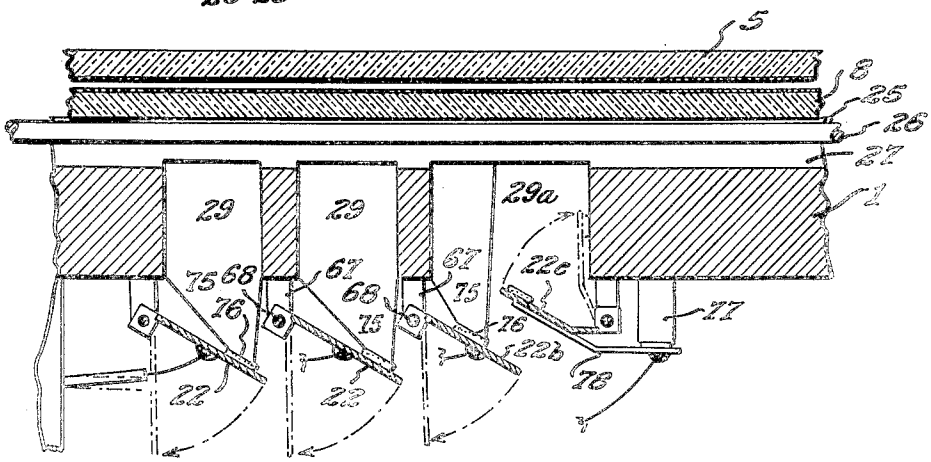


FIG. 14.

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Patented Nov. 27, 1951 2,576,759

UNITED STATES PATENT OFFICE

2,576,759

METHOD AND MEANS FOR PRODUCING TUNES AND VOICES PHOTOELECTRICALLY

Edward M. Jones, Cincinnati, Ohio, assignor to The Baldwin Company, Cincinnati, Ohio, a corporation of Ohio

Application September 22, 1949, Serial No. 117,239

48 Claims. (Cl. 84—1.18)

1

My invention relates to electrical musical instruments of the photo-electric type, wherein a moving member carries a plurality of pitch tracks dividing incident light into traveling beams, and wherein the traveling beams on their way from a light source to a photoelectric cell pass through and scan voicing representations through the agency of which pulsations are set up characteristic of desired fundamental frequencies and desired related harmonics in desired amplitudes for the production of voices.

An object of the invention is the provision of a self-contained, relatively small, and simple generator capable of producing and combining tones within the range of the full tonal scale of a desired keyboard instrument, together with a wide variety of voices.

It is an object of my invention to provide a combination of pitch disc and voice disc of relatively small area but coacting to produce a large number of tones and a large number of voices.

It is an object of my invention to provide a generator in which a division of voices may be obtained, either as respects different parts of the same keyboard or as between different keyboards such, for example, as an organ manual and a pedal clavier.

It is an object of my invention to provide a mode in which tones and voices which are lost by reason of voice shutter divisions may be separately supplied in the same organization of parts.

It is an object of my invention to provide a standardized series of parts making up a self-contained generator which with or without changes in a pitch disc and a voice disc may be employed either for a single manual keyboard instrument with a divided keyboard, or in tandem for multi-keyboard instruments including a plurality of manuals and a pedal clavier.

It is an object of my invention to provide in a generator, and particularly in connection with a generator shutter system, a means and method for octave coupling as hereinafter set forth.

It is an object of the invention to provide means and a method for securing the maximum number of voices and tones from a voice disc and a pitch disc containing a minimum number of pitch tracks.

These and other objects of the invention which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, I accomplish by that procedure and in that construction and arrangement of parts of which I shall now describe exemplary embodiments having to do with single manual and multi-manual keyboard instruments. Reference is made to the accompanying drawings wherein:

Figure 1 is a top plan view with certain parts broken away, of a generator which I may employ.

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Figure 2 is a vertical sectional view of the generator taken along the section line 2—2 of Figure 1.

Figure 3 is a vertical elevational view of the same generator.

Figure 4 is a partial plan view of a shutter plate mechanism showing the disposition of the wire shutter elements and modes of octave coupling which I may employ.

Figure 5 is a partial plan view of a voice disc for a single manual instrument having a divided keyboard, with a portion of the disc broken away to show a part of the pitch disc.

Figure 6 is a diagrammatic representation illustrative of a mode of machining grooves in a shutter plate.

Figure 7 is a diagrammatic illustration of voicing representations designed to produce harmonically related voices from a single pitch track.

Figure 8 is a partial plan view of a voice disc for a two manual instrument.

Figure 9 is another partial plan view of a voice disc for a two manual instrument.

Figure 10 is a partial plan view of a voice shutter arrangement such as may be employed on a single manual instrument.

Figure 11 is a partial perspective view of a voice shutter element.

Figure 12 is a partial perspective view of a voice shutter element showing means for the attachment of an actuating wire.

Figure 13 is a partial sectional view taken through a shutter plate, voice disc and pitch disc such as a view along the section line 13—13 of Figure 10.

Figure 14 is a partial sectional view through a shutter plate, voice disc and pitch disc taken along the line 14—14 of Figure 10, and showing the operation of the voicing shutters.

Generator assembly

This application is related to my copending application entitled Generator for Electric Pulsations of Audio Frequency, Serial No. 108,946, filed August 6, 1949, now U. S. Patent No. 2,558,653 granted June 26, 1951, inasmuch as it makes use of a generator of the same general type. The said copending application pertains to the physical organization of the main parts of such a generator. I shall first herein describe the generator broadly so that the subsequent teachings herein may be fully understood. Reference is made to Figures 1, 2 and 3, wherein it will be seen that the generator as such is built on the foundation of a shutter plate 1. The shutter plate is generally of the type set forth in the copending patent of John F. Jordan, No. 2,506,599, granted May 9, 1950, and entitled Shutter Mechanism, and will be hereinafter more fully

described together with certain modifications therein.

Centrally of the shutter plate there is a boss 3 or bearing holder with respect to which a pitch disc 5 is journaled for rotation by means of a hub 6 and a shaft 7. A voice disc 8 rests directly upon the shutter plate as will be seen most clearly in Figure 2.

A lower can or casing element 9 is affixed to the shutter plate. It contains a light source 10 in a suitable fitting 11, and a parabolic mirror 12. There is an upper can or housing indicated generally at 15, which contains a photoelectric cell 16 and a parabolic mirror 17. It will be understood that light from the light source 10, reflected by the mirror 12 is passed upwardly through openings in the shutter plate 1, through voicing representations on the voice disc 8, through pitch tracks on the pitch disc 5, and is reflected by the parabolic mirror 17 to the photoelectric cell 16.

The pitch disc 5 has a peripheral armature 18 which is directly driven by electromagnetic means including the inside C-core and winding 19 and the outside E-core and winding 20 constituting with the armature 18 an eddy current motor. Within the scope of this invention the pitch disc 5 may be otherwise driven. Where the specific illustrated construction is employed, the motor parts are contained within an extension of the can or housing 15 as shown, the magnetic cores and windings being supported thereby.

The photocell 16 and another photocell 21 which is employed in connection with speed control and vibrato tracks 37 and 38 on the pitch disc are supported on a bracket 21*a* within the upper can or housing 15; and this bracket may also support other electrical parts such as a preamplifier and the electric circuit elements pertaining to the speed control and vibrato mechanism. The speed control and vibrato means are described and claimed in a copending application of myself and George F. Williamson, entitled Systems for the Production and Use of Electric Oscillations for Control Purposes, Serial No. 117,240, filed September 22, 1949.

The principles of the present invention are preferably incorporated in a general organization of parts such as has just been described; but this general organization is not a limitation on the present invention otherwise as set forth in the appended claims.

The shutter plate

The shutter plate 1 hereinabove referred to is of the type having arcuate grooves generally responding, over half their circumferential extent to the circular pitch tracks on the pitch disc 5. From the bottoms of these grooves light openings extend through the shutter plate to its lower side, and arcuate wires operate as actual shutters in the arcuate grooves, moving from side to side of said grooves in response to longitudinal increments of motion applied to the wires.

The light openings are arranged in series with the several wires simultaneously opening up a plurality of them; and series of voicing representations on the voice disc 8 are associated with the several series of openings, all as hereinafter more fully described, so that voicing shutters such as the shutter diagrammatically indicated at 22 in Figure 2 may be employed for each voice. The several voicing shutters are operated by wire elements; and prolongations of these elements, as well as the wires attached to the arcuate wire shutter elements, are passed through sheaths forming Bowden transmissions. Certain of the shutter wire transmissions are indicated at 23 in Figures 1, 2 and 3 and certain of the voice shutter transmissions are indicated in Figures 2 and 3 at 24. It will be understood that in the instrument the shutter wire transmission elements will be connected directly or indirectly to respective playing keys of one or more manuals and a pedal clavier where this is provided, and that the transmissions operating the voice shutters 22, and indicated at 24, will be connected directly or indirectly with stop tabs or other voice selecting devices accessible to the performer. As will be pointed out hereinafter, more than one voice shutter 22 may be associated with the same stop tab. Keys and stop tabs have not been illustrated herein but will be part of an instrument console in which one or more of my generators will be installed.

The shutter plate may be made by machining or molding or a combination of the two. A convenient mode of manufacture comprises forming in one face of the plate, as shown in Figure 13, a plurality of grooves 25 within which will lie the arcuate shutter wires 26, the grooves being wider than the cross sectional dimension of the wires so that the wires can move from side to side of the grooves. Deeper, but narrower grooves 27 are cut or formed downwardly from the bottom of the grooves 25, the said deeper grooves being narrower than the cross sectional dimension of the shutter wires. Preferably one edge of the deeper grooves approaches but does not coincide with an edge of the first mentioned grooves, so as to leave a shoulder 28 insuring completion of the cutting off of the light when the shutter wire is in closing position. In the opposite side of the plate I machine or mold a plurality of recesses 29 which cut across the various pitch tracks or a desired group of them, and, intersecting the deeper grooves 27, provides the light openings which are opened and closed by the shutter wires. Such an arrangement and mode of manufacture is that described in the said Jordan Patent No. 2,506,599.

It will be understood that the grooves in which the shutter wires lie must correspond substantially with the pitch tracks on the pitch disc 5; and these pitch tracks are circular. However, the passage of light from the light source to the photocell occurs through light openings located in only approximately one-half of the area of the shutter plate. As a consequence, the correspondence of the grooves with the pitch tracks need occur only in the half of the shutter plate so used. Indeed, the remaining half of the shutter plate has its grooved surface cut away or lowered, excepting for a rim, so as to provide room for the operating Bowden transmission connections to the several shutter wires. The cut away area of the plate is indicated generally at 30 in Figure 4. In the light of these considerations it has been found possible to devise a way of continuously machining the grooves with a gang tool. Referring to Figure 6, which is a diagrammatic representation, circles 31, 32 and 33 are concentric with their centers at 34 and are representative of pitch tracks. A spiral dashed line 35 is representative of a spiral line of cut formed by a gang tool moving progressively radially of a shutter plate blank mounted and rotated by a lathe. By decentering the plate in the lathe so as to establish a new center 36, the correspondence of the spiral with the concentric

circles will be as illustrated; and it will be noted that the spiral substantially corresponds with the concentric circles over the entire lower half of the diagrammatic figure. In actual practice the distance of decentering will be determined by the dimensions and spacing of the grooves and pitch tracks.

Dimensions are not a limitation on the present invention. However, one of its advantages is that I may secure the full tonal range desired for a keyboard instrument, plus a large number of voices in a generator of small overall dimensions. Thus in practice I space my pitch tracks on a pitch disc one-sixteenth inch on centers and thus find it possible with a pitch disc of approximately 13½ inches in diameter to provide enough pitch tracks to accommodate all of the seventy-three notes desired for a single manual organ or all of the sixty-one notes desired for a given manual in a two manual organ plus twelve or thirteen others such as may be desired for connection with a pedal manual, plus a number of replacement tones which may be required in connection with a division of voicing shutter means as hereinafter explained at length. Also on the same pitch disc I may provide two outer, wider tracks, one being for the purpose of speed control, and the other being for the purpose of providing vibrato. In connection with such a pitch disc I provide a shutter plate in which the grooves **25** are .053 inch in width and spaced .0625 inch on centers. The narrower and deeper grooves **27** are preferably .017 inch in width, and the wire shutter elements **26** have a diameter of .028 inch. In the cut away portion **30** of the shutter place the shutter wires **26** are preferably joined to actuating wires of smaller diameter in the sheaths aforesaid, forming the Bowden transmissions, so as to provide room for these transmissions; and the transmissions **23** are preferably carried away from the shutter plate through perforations in the rim thereof as illustrated in Figures 1, 2 and 3. This provides a dust-tight construction, in view of the cans or housings **9** and **15**, and their associated parts. The series of Bowden transmissions **24** for operating the voicing shutters may be similarly carried from the shutter plate through holes in the rim thereof, or may be kept underneath the plate and carried, as illustrated in Figures 2 and 3, through a recess or recesses formed in a grooved configuration on the under side of the shutter plate **1**, which configuration accepts an edge of the lower can or housing **9**, there being a dust-tight packing at the juncture of the elements and around the transmissions.

Means for coupling

A shutter plate of the wire-and-groove type, as hereinabove generally described and as set forth in the said Jordan Patent No. 2,506,599, has the advantage that movement of a single shutter wire will open up or close a plurality of light apertures about the shutter plate. These apertures may be arranged in a plurality of series associated with various voicing representations so that there is provision not only for the selection of voices but also for the additive combination of voices. However, coupling is a desirable feature of a keyboard instrument of the organ type for various purposes: It is frequently desired that additive voices sound with respect to each other not at the same fundamental frequency but at fundamental frequencies which are harmonically related to each other. Thus,

a voice may be desired as a 4-ft. voice, another additive voice as an 8-ft. voice, a third as a 16-ft. voice and so on. Again, ordinary octave coupling irrespective of voice may be desired.

In accordance with my invention I make provision in my shutter plate for coupling. Reference is now made to Figure 4 wherein a shutter plate **1** is diagrammatically indicated. For the sake of simplicity I have not illustrated the grooves but, instead, have illustrated a plurality of shutter wires which will be understood as lying within the grooves. In this illustration the specified letters C demark the confines of groups of wires for the respective half tones of consecutive octaves of the musical scale. Seven wires per octave have been shown in the drawing to avoid undue complexity of lines; but it will be understood that the octave of the equi-tempered musical scale contains twelve semitones and hence in practice there would be twelve shutter wires per octave.

One way of securing the coupling to which I have referred above is accomplished by cutting away or recessing the plate so as to interrupt the continuity of the grooves over certain areas indicated generally in the figure at **39** and **40**. The grooves are, of course, concentric and will be understood in the figure as formed on the shutter plate in areas generally indicated at **41**, **42** and **43**. If any group of shutter wires lying between the indicia C on the drawing are followed, it will be seen that they lie in a series of concentric grooves for one octave in the grooved area **43** and, leaving that area they pass in the ungrooved space **40** to the grooves for the next higher octave in the grooved area **42**. Leaving that area, they cross over to the grooves for the second higher octave in the ungrooved area **39**, and then follow the last mentioned arcuate grooves in the grooved area **41**. One end of each shutter wire is anchored to the shutter plate at the upper right in the figure.

What has been stated above applies to the shutter wires for all of the octaves in the instrument excepting the highest and the lowest. Thus the highest group of shutter wires marked **44** in the figure traverses in the area **43** concentric grooves for the second highest octave provided by the pitch disc, then transfer in the ungrooved area **40** to the groves for the highest octave provided by the pitch disc in the grooved area **42**. This particular group of wires is anchored to the plate at **45**. The group of wires marked **46** does not traverse any grooves in the area **43** but enters the lowermost octave group of grooves in the grooved area **42**, transferring in the ungrooved area **39** to the next higher octave group of grooves in the area **41**, the wires being anchored at **47**.

The voicing representations on the voicing discs will be allocated to series corresponding with series of light openings in the shutter plate lying in the grooved areas **41**, **42** and **43**. In my instrument the grooved area **43** may, in general, have light openings arranged in series for what may be regarded as 16-ft. tones; the 8-ft. tones will generally be allocated to the series of light openings in the grooved area **42**; and the 4-ft. tones will generally be allocated to series of openings in the grooved area **41**. This is only a matter of convenient terminology since the actual frequency of a tone produced by light passing through any given pitch tract can be determined within limits by other factors, as hereinafter set forth. But the terminology will serve to illus-

trate an aspect of octave coupling accomplished by this phase of the invention. Thus, following a particular shutter wire, say the shutter wire **48**, for a C note, it will first traverse grooves in the grooved area **43** in which area actuation of the wire will open up one or more light openings overlying a pitch track appropriate to C–65. In the area **42**, however, the same wire will traverse a groove and open up one or more light openings therein, related to a pitch track for C–131, i. e., a C note with a frequency of 131 cycles per second, while in the area **41** it will traverse a groove and open up one or more light openings therein overlying a pitch track appropriate for a C note of 262 cycles per second.

Where octave coupling is practiced, as hereinabove described, where the pitch tracks on the pitch disc are arranged in accordance with successive octaves of the musical scale, and where in the ungrooved areas the individual wires must skip a distance equal to the radial span of 12 pitch tracks on the pitch disc, it is well to have them extend tangentially in the ungrooved areas of the plate and with this in mind the ungrooved areas are so proportioned that a straight line or tangential projection of a shutter wire as it leaves one grooved area, will bring it to the proper position at the beginning of the next grooved area, all as will be appreciated from the diagrammatic showing of Figure 4.

I am, of course, not restricted to octave coupling and where coupling at some other harmonic relationship is desired, the configuration of the plate may be such that the various wires will traverse grooves in one grooved portion and then skip to other grooves in the next grooved portion bearing an harmonic relation to the first grooves and their pitch tracks other than an octave relation.

However, there is another way of securing coupling which is also illustrated diagrammatically in Figure 4. If the wire **49** be followed, it will be seen that it traverses in the grooved section **43** a particular arcuate groove, whence in the space **40** it skips to the next innermost groove on the shutter plate, again skipping inwardly to the second innermost groove in a grooved section of the plate indicated at **50**. This will illustrate the fact that where the radial distance skipped by any particular shutter wire is not great in the radial direction, I am by no means restricted to a tangential extension of the shutter wire in ungrooved areas of the plate.

The pitch disc

The various pitch tracks and the speed control and vibrato tracks on the pitch disc are preferably formed by photographic means; and the pitch disc is preferably a transparent member bearing the photographic representations. Glass is the material preferred by me by reason of its stiffness and dimensional stability. The various pitch tracks, although not specifically illustrated herein, will be understood as comprising series of transparent portions for each track in a generally opaque field, the tracks, of course, being concentric, and the circumferential widths of the transparent portions being limited in accordance with the fineness of the variations representing harmonics in the voice tracks to give proper scanning.

For the most part, the pitch tracks on the preferred form of my pitch disc are arranged to provide a series of successive octaves outwardly from a center portion of the disc, each octave as indicated above consisting of 12 pitch tracks. In such an arrangement the number of light openings in each track must bear a whole number relationship to the number of openings in the next track since each track must contain a whole number of openings. The exact ratios of the frequencies of the adjacent semi-tones in the equi-tempered scale cannot be expressed in commensurate numbers, as is well known; the ratios will, of course, be approximated more nearly in large whole numbers than in small ones. The frequency produced by any given pitch track will, of course, depend upon the number of light openings in it and the speed of rotation of the pitch disc. For accuracy of representation it is desired that the numbers of light openings in a given track be as small as possible. Nevertheless with a given and relatively slow speed of rotation of the pitch disc, it is quite possible to select a whole number series of light openings in the various pitch tracks which will approximate the semi-tones in 6 or 7 octaves of the equi-tempered scale without having the number of openings become too large in the pitch track for the highest note of the series.

My invention is not limited to any particular series and various series may be employed. However, with a pitch disc rotating at a speed of 33.3 R. P. M., I employ a pitch track for the lowest C note of the instrument having 58 openings and this gives me a C note of a frequency of 33 cycles per second. The number of light openings in the pitch tracks scales upwardly to 3712 openings, which at the speed of rotation of the disc gives me a frequency for a high C note responding to 2093 cycles per second. An example of a series for a pitch disc which is entirely satisfactory is set forth in the attached schedule, said series being generally similar to that disclosed by Armand F. Knoblaugh in his co-pending application on Serial No. 39,674 entitled Musical Instruments Employing Continuously Moving Members; and it will be noted that as the frequencies ascend, minor whole number corrections have been made in successive octaves to bring about still greater accuracy:

Notes	Number Of Slots	Notes	Number Of Slots
C1	3712	B4	438
B1	3504	A#4	414
A#1	3308	A4	390
A1	3124	G#4	368
G#1	2948	G4	348
G1	2780	F#4	328
F#1	2624	F4	310
F1	2476	E4	292
E1	2340	D#4	276
D#1	2208	D4	260
D1	2084	C#4	246
C#1	1968	C5	232
C2	1856	B5	219
B2	1752	A#5	207
A#2	1654	A5	195
A2	1562	G#5	184
G#2	1474	G5	174
G2	1390	F#5	164
F#2	1312	F5	155
F2	1238	E5	146
E2	1170	D#5	138
D#2	1104	D5	130
D2	1042	C#5	123
C#2	984	C6	116
C3	928	B6	109
B3	876	A#6	103
A#3	827	A6	97
A3	781	G#6	92
G#3	737	G6	87
G3	695	F#6	82
F#3	656	F6	77
F3	619	E6	73
E3	585	D#6	69
D#3	552	D6	65
D3	521	C#6	61
C#3	492	C7	58
C4	464		

In Figure 5 I have illustrated a portion of the pitch disc 5, and diagrammatically represented thereon pitch tracks for a consecutive series of octaves which are six in number, this being suitable for the uses of most keyboard instruments. It will be obvious that by varying the dimensions of the pitch tracks or the dimensions of the pitch disc a greater or lesser number of octave series may be placed thereon. Representative dimensions for a commercial instrument have been given hereinabove. In Figure 5 the six octave series are indicated respectively at 51 to 56 inclusive. Outwardly beyond the last octave series 56 the pitch disc bears a pitch track 37 for speed control purposes and a track 38 for vibrato. The circuits used in connection with these tracks are described in connection with another application noted hereinabove. It is sufficient to note here that the track 37 is used in connection with the photocell 21 and appropriate circuit elements in connection with the eddy current motor 19, 20 to maintain a constant speed in the pitch disc, while the track 38, containing light openings arranged to pass a given point at a suitable sub-audio frequency, is employed to vary the constant speed of the pitch disc in a rhythmic manner so as to impart to the reproduced tones a pitch tremolo or vibrato. The tracks 37 and 38 are ordinarily made much wider than the pitch tracks, and with much larger openings in the shutter plate so as to take advantage of a larger amount of the incident light.

Inwardly of the innermost octave series of pitch tracks 51, there is space on the pitch disc for another series of tracks indicated in Figure 5 at 57. This series may be used for various purposes. For example, in a keyboard instrument having a manual and a pedal clavier, the pitch tracks of the series 51 to 56 may be connected with the keys of the manual, while pitch tracks of the series 57 may be employed to supply notes for the pedal clavier. Again, in such an instrument, some only of the octave series 51 to 56 may be employed for the manual, and the remainder for the pedal clavier, but in this instance it may be desirable to supplement the range either of the manual or of the pedal clavier, in which event pitch tracks of the series 57 may be employed for this purpose.

But in an instrument where the pitch tracks lie very closely together radially and the tolerances are small, the division of pitch tracks either as respects a single manual, between different manuals, between a manual and a pedal clavier, or between different voices (all of such divisions involving a division of voice shutters as hereinafter more fully taught) one or more pitch tracks may lie at the point of division of voice shutters where neither shutter can be relied upon accurately to cover the particular pitch track or tracks. Where this is encountered, the effect of one or more pitch tracks may be lost as respects a particular pair of voices or group of paired voices, and hence in the practice of my invention I do not provide light openings at these particular points for these particular pitch tracks. Where this is encountered it is necessary to supply the effectively missing pitch tracks elsewhere, and in this event pitch tracks of the group 57 are utilized.

Referring to Figure 4 let it be supposed that by reason of any of the divisions mentioned above, the groove representing the note B–62 will fall at the meeting lines of shutters in the grooved area 43, while the corresponding octavely related

note B–123 will similarly fall in the area 42 and that there will be a similar obscurement of the pitch track B–247 in the area 41. Under these circumstances I provide in the group 57 in Figure 5 pitch tracks for B–62, B–123, and B–247 located inwardly of each other in the order named. The wire 49, previously traced, traverses the groove for the inner pitch track, B–62, in the area 43, then the next inward pitch track groove in the area 50 for B–247. If I desire to extend certain voicing series to employ a pitch track which may not otherwise be used in conjunction with other voicing series because of shutter divisions, the wire 49 may be coupled to the wire 58 for the normal B–62 groove as shown at 59.

Voice shutter arrangements

In Figure 4 there are certain dotted line representations indicative of series of voice tracks on a voice disc. These are generally directed so as to cut across a plurality of the pitch tracks on the pitch disc. Most of them have an extent sufficient to cover a plurality of octaves; an exemplary arrangement is a group 60 of them which are only one octave in extent. Another exemplary one 61 is four octaves in extent. Still others are interrupted at a point intermediate their length. For example the voice track group 62 extends inwardly over a range of notes from C–2093 to C–131, while continuation marked 62*a* extends inwardly from the semi-tone next below B–123 to C–33, and picks up the semi-tone B–123 in a pitch track of the group 57 hereinabove discussed. The voices produced by the voice tracks in the sections 62 and 62*a* may be the same or different; but in the particular embodiment, as will hereinafter be more fully explained, one may be desired without the other, or both may be desired simultaneously, and hence different voice shutters will be required for the sections 62 and 62*a*, which shutters may be operated simultaneously or independently. Finally, I have shown a pair of voice track series 63 and 64 which, in the particular embodiment, are located very close together, and this gives rise to a particular problem in the provision of voicing shutters. The series 63, 64, may also be divided intermediate their lengths as hereinabove described.

I have already indicated the provision of voice channels or recesses 29 in the underbase of the shutter plate 1, and the association of voicing shutters with these channels. The light passing through the pitch disc, the voice disc and the shutter element is in parallel beams, for which reason the voice shutters need only be relatively elongated, pivoted panels which in one position do not obstruct the parallel beams passing through any given series of voicing representations, and in another position act to cut them off. Various constructions may be adopted for the voice shutter. A simple and convenient one is illustrated in Figures 10 to 12 and 14. Here a voice shutter 22 is an elongated strip of metal, preferably darkened as to surface so as to be non-reflective, and provided along one edge with turned up ears 65 perforated as at 66. Three posts 67, having similar perforations, are threaded into or otherwise mounted on the underside of the shutter plate 1, as will be most clearly appreciated from Figures 10 and 14. The shutters 22 may conveniently be pivoted on the posts by means of a wire pintle 68. Where two or more shutters are in alignment for use with a divided voicing series, as at 22 and 22*a* in Figure 10, the

same pintle 68 may serve for a plurality of shutters. The ends of the shutters will be properly configured to follow the pitch tracks as will be evident from Figure 10.

The wire elements for actuating the voice shutters may be pivoted to them at points remote from their pivotal connections with the posts 67 in any suitable way. One inexpensive, simple, but positive way is illustrated in Figure 12, where the voice shutter 22 is slotted as at 69, slitted as at 70, and indented as at 71 and 72. A wire actuating element 73 having a turned over end 74 may be engaged with the shutter from the opposite side and then swung over to the position illustrated in Figure 12, whereupon a pivotal connection will be formed.

It is desired to provide stops for the voice shutters in their closed position, and to this end I attach to the shutter plate 1, post-like stop members 75 having felt pads 76, forming abutments engaging the shutters 22 at one end when they are in closed position, the pads 76 insuring quiet operation of the shutters.

In Figure 14 I have shown at 29*a* a voice channel of more than usual width and designed to accommodate the closely juxtaposed voicing series 63, 64, hereinabove described. In providing shutters for these series, I adopt a construction shown in Figure 14. Here there is a shutter 22*b* for the series 63 or parts thereof. This shutter swings toward the element 1 in approaching closed position. A second voice shutter 22*c* for the series 64 or parts thereof, is arranged to swing inwardly or toward the main shutter plate 1 in approaching the open position. As will be appreciated from the dotted line showing in Figure 14, the edge of the voice channel 29*a* will serve as a stop for the voice shutter 22*c* in open position. In order to provide a stop for it in closed position I mount a bracket 77 on the plate 1 and provide an arm-like abutment 78 for the voice shutter. The arrangement just described has the advantage that both shutters 22*b* and 22*c* may be operated by wire-like operating elements extending in the same direction.

The particular arrangement of voice shutters may be varied as desired. In the exemplary instruments to which this case relates there is a series of voice shutters 22*d* taking care of the short voicing representations of the series 60. The divided voicing series 62, 62*a* will be taken care of by voice shutters 22*e* and 22*f*, and other divided series will be taken care of in a similar manner. The juxtaposed series 63, 64, will be taken care of as hereinabove described by voice shutters 22*b* and 22*c*, and their counterparts 22*g* and 22*h*. It will also be noted in Figure 10 that there is a shutter 79 for an opening 80 in the main shutter plate 1, which opening permits passage of light through vibrato track 38 on the pitch disc. Another opening 81, in the main shutter plate 1 permits passage of light through the speed control track 37, but since speed control will always be in operation, no shutter need be provided for this opening. The vibrato shutter will, of course, be connected to a suitable stop tab, or control knob, on the instrument, the latter together with the shutter 79, providing means for stepless control of the extent of the vibrato.

It may be noted that the voicing shutters of the series 22*d* are made progressively longer so that their wire operating elements can come away from them in side by side relationship. This is shown in Figure 10. Other modifications may be made without departing from the scope of my invention as to the shape, arrangement, construction and mode of operation of the voicing shutters.

Voice discs

In the perferred embodiment of my invention the voice disc is a transparent element having a generally opaque coating. The individual voice tracks thereon are transparent areas following the concentric arcuate disc position of the several pitch tracks to which they pertain and varying throughout their entire length either in area or in transparency so as to impart variations to the moving beams produced by the transparent areas of the rotating pitch disc. I prefer to use a voice disc of glass, by reason of its dimensional stability, and to employ in connection therewith a photographic representative of the opaque areas and the transparent areas hereinabove mentioned. The individual voicing representations will usually be a plurality of cycles long, an arrangement which is preferred by me for several reasons. In the first place a voicing representation several cycles in length permits the use of a plurality of traversing beams and hence a greater quantity of light incident on the photocell 16 per note per voice. In the second place, the use of a plurality of beams simultaneously per note per voice diminishes extraneous noise due to imperfections in the pitch tracks.

While there will be on any keyboard instrument a general, over-all volume control associated with the amplifier, it will be understood that a general difference in the sound level of different voices may be desired, some voices sounding best as soft voices while others are preferably of greater volume. This may be accomplished by so forming the voice disc initially as to provide greater variation in transparency in the voice track representations for loud voices than in those for soft voices.

The opaque area surrounding each individual voice representation on the voice disc will act as a window therefor, so that as one moving beam enters the voice representation another relieves it. Thus the perforations for the passage of light in the main shutter plate 1 do not need to serve as windows and hence do not have to be made with sufficient accuracy for that purpose.

The general design of the main shutter plate, the note shutters, individual or coupled, and the voicing shutters will be appreciated from the description above. It will be understood further that in the embodiment shown there will be a series of light openings in the main shutter plate 1 for each series of voicing representations on the voice disc, that there will be a voice channel on the under surface of the main shutter plate 1 for such series, that one or more voice shutters will be associated with each such series, and that the series of voicing representations on the voice disc will match up with the series of openings, and shutters, on the main shutter plate. The particular arrangement illustrated in the figures of this application is a convenient one for commercial instruments, but is not otherwise limiting and may be considerably varied within the space limits of any particular generator. The nature, moreover, of the particular voices represented on the voice disc is not a limitation on the present invention. The specific voices may be any desired for the uses of a particular instrument and, indeed, on any given instrument the voices may be changed if desired by substituting one voice disc for another in the genera-

tor. Voice discs may be otherwise made; but I prefer to make them for my instrument by first producing a master record photograhically by varying beams of light in accordance with the electrical pulsations of a generating apparatus in which I can control the frequency and volume of the fundamental and the amplitude and phase of a plurality of harmonics which may be varied both as to amplitude and phase and as to volume. In this way the characteristic tones of existing instruments can be duplicated and other tones can readily be created. From the master copy other voice discs can be made by photographic reproduction. A voice disc in my particular generator is suported by the main shutter plate 1 and serves to close the grooves therein containing the shutter wires 26 for the individual notes. It has a central perforation which fits over the bearing holder 3 (Figure 2), which therefore serves to center the voice disc.

The rotative position of the voice disc may be fixed by clamps or other suitable means (not shown) engaging its periphery.

Where a particular pitch track is not usable, or "lost," by the juxtaposition of the edge of two voicing shutters pertaining to the same voicing series, as hereinabove described, the voice track of the series for the particular "lost" note will simply be omitted or blacked out on the voice disc. This makes it unnecessary to provide a variation of the shutter structure to take care of this situation.

I have hereinabove indicated that the voicing series pertaining to the grooved area 43 of the main shutter plate 1 may, if desired be so-called 16-foot voicing means divided or not as desired. The main voicing series such as the series 61, 62, 63 and 64 in the grooved area 42 of the main shutter plate may be 8-foot series, while the series of voicing representations 82 in the grooved area 41, divided or not, may be so-called 4-foot series. In the exemplary embodiment the particular series designated in Figure 4 at 83, which lies in the area 41, is intended for use as a 2-foot series. Also, the short series designated at 60 which lie in the grooved area 42, is used for 4-foot and 2-foot voices. It will be noted, however, that these particular series are juxtaposed to the same pitch tracks which are employed for 8-foot and 4-foot voices of the same frequencies as represented by the occurrence of transparent areas in the same pitch tracks. The respective octave differences between the 16, 8, and 4-foot voices is taken care of by the octave coupling accomplished on the main shutter plate as hereinabove described. But this is not true of the octave differences between 4-foot and 2-foot voices, or the double octave differences between 8-foot and 2-foot voices in the particular embodiment shown. While it is within the scope of my invention to provide additional stages of octave coupling as will be readily apparent to the skilled worker in the art in the light of these teachings, there is another way of obtaining octave relationships which I make use of in the exemplary embodiments herein illustrated.

It will be understood that in my instrument the voicing representations control the fundamental frequencies of individual notes as well as their harmonic contents. In Figure 7 I have shown at 84 a simplified voice representation of sine wave form having a periodicity or fundamental frequency represented by the distance between dot-dash lines 85 and 86. But I have also illustrated directly therebelow another simplified sine wave voice representation 87 having a cycle length represented by the distance between 85 and 88 or 88 and 86. If a light beam traverses the voice representation 84 a series of light beams spaced apart the distance between 85 and 86 traverse voice representation 84 at a particular speed and then impinge on a photocell, the light so impinging will be caused to fluctuate at a certain cyclical rate. If however the same beams moving at the same speed traverse the vioce representation 87 the frequency of the cyclical variations will be doubled. I have shown also a third voice representation 89 in which the variations are half the length of those in 87 and one quarter the length of those in 84. The same beams traversing the voice representation 89 at the same speed will produce cyclical light variations having a frequency twice or four times the frequency of the previous cases respectively.

While the voice tracks in Figure 7 have been shown as simple sine wave tracks, it will be understood that they may incorporate periodic variations additionally imparting harmonics of selected amplitude and number. In order to produce a successful result under these circumstances it is only necessary that the effective width of the transparent areas in the pitch track be narrow enough to scan the variations of the voice track properly. Thus within certain limits it is quite possible to secure 4 foot or 2 foot voices, for example, from pitch tracks which would normally produce 4 foot or 8 foot voices if they were employed to scan voice representations having cyclical variations equivalent in length to the distance between the transparent areas of the pitch tracks. In the particular embodiment of my invention I employ these principles in connection with the voicing representations of the series 83 and 60.

The representations specifically indicated at 60*a* are used to extend the series 83 an additional (higher) octave. Since the latter represents a 2-foot voice in the normally 4-foot sections 41, it may be composed of "double" wave forms as shown at 87 in Figure 7. It will then follow that the group 60*a* will be "quadruple" wave forms, such as 89, since they must represent a 2-foot voice in the normally 8-foot section 42. It will be obvious then that it will be desirable that voice shutters corresponding to areas 83 and 60*a* be actuated by the same stop tab. Their respective actuating wires may be interconnected at the actuating stop tab, or in any suitable manner. A preferred construction is disclosed in a copending application in the name of Merton D. Corwin, entitled The Construction of Photoelectric Organs, Serial No. 181,630, filed August 26, 1950. In a similar manner, other voicing shutters in the group 22*d* will be operated simultaneously by the stop tabs connected to the voicing shutters corresponding to the series 82, so that the 4-foot voices represented thereby may be extended an additional (higher) octave. The areas 60*b*—60*d*, as pointed out above, will be double wave forms since they relate to 4-foot voices in the normally 8-foot area 42.

The specific nature of the voices involved does not form a limitation on the invention, and may be any desired.

General voice arrangements

One of the objects of the invention is to provide a generator assembly which will serve the purposes of a variety of keyboard instruments and which, in that function, will be as nearly standardized as possible. By a variety of keyboard

instruments I mean those ranging from single keyboard instruments (usually without any pedal clavier, although a pedal clavier may be added if desired) to plural keyboard instruments which also include a pedal clavier and which have both a large number of voices and a wide variety of voices. The constructional features hereinabove described enable me to accomplish this.

A single manual instrument, especially one without a pedal clavier, will normally have a divided keyboard with provision for securing the same or different voices in the bass and treble sections as well as the provision of voices individual to the two sections, and differing as to number. In Figure 5 I have illustrated an exemplary arrangement for a single manual instrument of the divided keyboard type. Assuming that the inward sections of any divided voice series on the illustrated voice disc are associated with shutter wires connected to the playing keys in the bass section of the manual or keyboard and the remaining portions of these sections plus others have their shutter wires connected to the keys in the treble section, it will be noted that the particular arrangement illustrated provides the following:

One single-octave 16-foot voice for the bass section,
Three two-octave 8-foot voices for the bass section,
Three two-octave 4-foot voices for the bass section,
Two four-octave 16-foot voices for the treble section,
Four four-octave 8-foot voices for the treble section,
Three four-octave 4-foot voices for the treble section, and
One four-octave 2-foot voice for the treble section.

A greater or lesser number of voices may be provided by increasing or diminishing the number of series of voicing representations and shutter mechanisms in the light of the teachings above. The point of division between voices may be varied by varying the respective lengths of the two voice shutter plates appropriate to any particular voicing series so as to change either the point of division in the keyboard itself for all voices or the points of division of different voices as respects the same keyboard.

The voice disc arrangement illustrated in Figure 5 is also appropriate for use in a single manual instrument having a pedal clavier. In such an instrument the extent of the keyboard is usually less than that of an instrument having no pedal clavier. Where a pedal clavier is employed, the shutter wires and voice shutter mechanisms for those voice series hitherto referred to as connected to the bass section will be connected to the pedal clavier, and the shutter wires and voice shutters for the remainder of the voice sections will be connected to the single manual keyboard.

In plural manual instruments having also a pedal clavier, I prefer to employ two generators one for each manual. Each of these generators will have what may be called a treble section which will be connected through the appropriate shutter wires to the playing keys of one of the manuals, while the voicing shutters for the same voicing series will be connected to stop tabs appropriate to that manual. What has hereinabove been referred to as the bass section voicing series will be connected in this instance through the appropriate shutter wires to the pedal clavier.

In Figure 8 I have illustrated diagrammatically a voice disc arrangement for the great organ manual of a two manual instrument. The lines of division between the sections of divided voice series in this instance have a different placement from the lines of division in the single manual arrangement of Figure 5. It will be noted that the particular arrangement of Figure 8 provides for the five octaves of the great manual:

One 2-foot voice.
Four 8-foot voices,
Three 4-foot voices, and
One 2-foot voice.

There is provided by this voicing disc, for use in connection with the pedal clavier:

Three one-octave 16-foot voices (in area 42) and
Three one-octave 8-foot voices (in area 41).

The arrangement of the voice disc for the swell manual generator is substantially the same and is partially illustrated in Figure 9. This voice disc and the generator in which it is located will furnish the same number of voices for the swell manual as that set forth above, together with voices for the second octave of the pedal clavier (using voicing representations of the type 87 in Figure 7).

Since different specific voices are usually desired for the great and swell manuals of an effective instrument, the voicing discs for the two generators in a two manual instrument will be specifically different. The generators for the two instruments, however, do not have to differ in any other respect.

Since the illustrated lines of division in divided voicing series are different as respects the voice discs for two manual and single manual instruments, this implies a different division of certain of the voice shutters for the several series, as will readily be understood. However, where a plurality of different kinds of voice shutters are kept in stock, they may be mounted by means of the pintle wires 63 on the same posts or supports 67, and this matter taken care of in the assembly of the instrument.

Where the lines of division between parts of voicing series differ the "lost" notes will likewise differ. However, extra pitch tracks in the group 57 (of Figure 5) may be provided for all of these "lost" notes, and the only other difference will lie in the note shutter wires at the inside of the main shutter plate 1 and the manner in which these are connected to the Bowden transmissions or with other shutter wires. This is also a matter which may be taken care of in assembly.

Thus, it will be seen that I have created a standardized design of generator in which the exception of the voice discs, certain of the voice shutters and two or three of the innermost note shutter wires, all parts are standard and invariable, while this standardized mechanism will meet the needs of a wide variety of keyboard instruments.

It will be understood that as manuals, beyond the great and swell manuals hereinabove referred to, are added to a complex organ, additional generators of my standardized design may be added, differing from those described above only in their voice discs, which may be altered to provide still other voices.

It will be apparent also that the standardized construction to which reference has been made, permits a wide variety of modifications to be accomplished and without alteration of the main

parts of the structure to adapt any particular instrument to specialized uses.

Modifications may be made in my invention without departing from the spirit of it. Having described my invention in certain exemplary embodiments, what I claim as new and desire to secure by Letters Patent is:

1. In a photoelectric musical instrument a shutter plate having in one surface grooves for containing shutter wires and openings extending through the plate from the bottom of said grooves, shutter wires in said grooves, said wires being capable of moving from side to side in said grooves to cover and uncover said openings, and means to so move said wires, said grooves being interrupted at intervals and said shutter wires passing, where said grooves are interrupted, from one groove to another groove which is not a prolongation thereof.

2. The structure claimed in claim 1 wherein said groove have an arcuate configuration in said plate and in which said wires follow arcuate paths in said grooves and substantially rectilinear paths where said grooves are interrupted.

3. The structure claimed in claim 1 wherein said grooves have an arcuate configuration in said plate and in which said wires follow arcuate paths in said grooves and substantially rectilinear paths where said grooves are interrupted, and in which said wires serve to cover and uncover a plurality of openings per groove in the uninterrupted sections thereof.

4. In a photoelectric musical instrument a shutter plate having arcuate grooves of substantially concentric arrangement in said plate, shutter wires lying in said grooves, said wires serving to cover and uncover light openings in the bottoms of said grooves by moving from side to side in said grooves, and means to so move said wires, said grooves being interrupted in common substantially radially directed areas so as to provide grooved areas and ungrooved areas on the surface of said plate, said shutter wires traversing the grooves of a grooved area arcuately, and passing rectilinearly in an ungrooved area to meet other grooves of the next grooved area, lying in said last mentioned grooves in an arcuate fashion.

5. The structure claimed in claim 4 wherein the grooves are arranged in a plurality of series of 12 concentric grooves each, representing the semi-tones of the equi-tempered musical scale and wherein in said ungrooved areas said wires pass from a groove for a particular frequency in a first grooved area to a groove for an octavely related frequency in the next grooved area.

6. In a photoelectric musical instrument of the type having a grooved shutter plate with light openings extending therethrough from said grooves and wires lying in said grooves to cover and uncover said light openings, coupling means comprising an interconnection between wire portions lying in different ones of said grooves whereby said wires are actuated simultaneously.

7. In a photoelectric musical instrument of a type having a rotating pitch disc with concentric pitch tracks thereon and a voice disc with a plurality of series of voice representations responding to said pitch tracks in position, a shutter plate having a surface provided with grooves responding to said pitch tracks in position, having series of light openings therethrough from the bottoms of said grooves and responding in position to said series of voice representations, and having ungrooved areas interrupting said grooves at intervals, and shutter wires lying in said grooves respectively and passing in said ungrooved areas from one set of grooves to another set of grooves progressively.

8. The structure claimed in claim 7 wherein said pitch disc has a plurality of said pitch tracks arranged progressively in the order of the semitones of a plurality of octaves of the equi-tempered musical scale, and in which said shutter wires pass from grooves in said first grooved area related to certain of said pitch tracks to grooves in a succeeding grooved area related to pitch tracks an octave higher than the first mentioned pitch tracks.

9. The structure claimed in claim 7 wherein said pitch disc has a plurality of said pitch tracks arranged progressively in the order of the semitones of a plurality of octaves of the equi-tempered musical scale, and in which said shutter wires pass from grooves in said first grooved area related to certain of said pitch tracks to grooves in a succeeding grooved area related to pitch tracks an octave higher than the first mentioned pitch tracks, and in which a plurality of different shutter wires lie in continuations of the same grooves in different grooved areas of said shutter plate.

10. The structure claimed in claim 9 including voicing shutters on the side of said plate opposite said grooves and acting to cover and uncover the several series of voicing representations on said voice disc.

11. The structure claimed in claim 9 including voicing shutters on the side of said plate opposite said grooves and acting to cover and uncover the several series of voicing representations on said voice disc, and in which the voice shutter for at least one of said series is interrupted intermediate its length to form two separately actuable voice shutter parts.

12. In a photoelectric musical instrument of a type having a rotating pitch disc with concentric pitch tracks and a voice disc bearing several series of voice representations, the series being directed transverse the pitch tracks, voicing shutters for said series divided intermediate their ends into a plurality of separately operable portions, the series of voicing representations provided with such shutters being divided into different voices for the different shutter portions.

13. A shutter plate having a plurality of substantially arcuate grooves formed in one face thereof, the opposite face of said plate having a plurality of recesses traversing said grooves, said plate having apertures opening from said grooves into said recesses, flexible, strand-like shutter elements lying in said grooves and movable to cover and uncover said apertures, and other shutter elements associated with said recesses to cover and uncover a plurality of apertures associated therewith, one at least of said last mentioned shutter elements being divided transversely into a plurality of separately operable portions.

14. A shutter plate having a plurality of substantially arcuate grooves formed in one face thereof, the opposite face of said plate having a recess traversing said grooves, said plate having a plurality of apertures opening from said grooves into said recess, flexible, strandlike shutter elements lying in said grooves and movable to cover and uncover said apertures, and a pair of shutter elements associated with said recess, each independently movable to cover and uncover different parts of apertures associated with said grooves.

15. The structure claimed in claim 14 wherein

one of said last mentioned pair of shutter elements is pivoted at one side of said recess and moves from covering to uncovering position away from said plate while the other of said shutter elements is pivoted at the other side of said recess and moves from covering to uncovering position in a direction toward said plate.

16. A shutter plate having a plurality of substantially arcuate grooves formed in one face thereof, the opposite face of said plate having a recess traversing said grooves, said plate having apertures opening from said grooves into said recess, flexible, strand-like shutter elements lying in said grooves and movable to cover and uncover said apertures, and a plurality of shutter elements associated with said recess to cover and uncover each less than the full number of said apertures.

17. A pitch disc for use with a voice disc having divided series of voicing representations thereon and divided voicing shutters, said pitch disc having pitch tracks concentrically arranged thereon, said pitch tracks comprising a first group arranged successively in accordance with the semi-tones of a plurality of octaves of the equi-tempered musical scale, and a second group of pitch tracks thereon some at least of which are for the same frequencies as pitch tracks in the first group to supply notes lost at the points of division of said series of voicing representations.

18. A pitch disc for use with a voice disc having divided series of voicing representations thereon and divided voicing shutters, said pitch disc having pitch tracks concentrically arranged thereon, said pitch tracks comprising a first group arranged successively in accordance with the semi-tones of a plurality of octaves of the equi-tempered musical scale, and a second group of pitch tracks thereon some at least of which are for the same frequencies as pitch tracks in the first group to supply notes lost at the points of division of said series of voicing representations, in combination with shutter means of wire-and groove type, and wherein wire shutter elements lying in separate grooves for the same frequencies are interconnected for concurrent operation.

19. A pitch disc for use with a voice disc having divided series of voicing representations thereon and divided voicing shutters, said pitch disc having pitch tracks concentrically arranged thereon, said pitch tracks comprising a first group arranged successively in accordance with the semi-tones of a plurality of octaves of the equi-tempered musical scale, and a second group of pitch tracks thereon some at least of which are for the same frequencies as pitch tracks in the first group to supply notes lost at the points of division of said series of voicing representations, in combination with shutter means of wire-and-groove type, and wherein the grooves of said shutter means are interrupted in groups, with a passage of said shutter wires from grooves of one group to different grooves of the next succeeding group whereby to effect coupling.

20. A pitch disc for use with a voice disc having divided series of voicing representations thereon and divided voicing shutters, said pitch disc having pitch tracks concentrically arranged thereon, said pitch tracks comprising a first group arranged successively in accordance with the semi-tones of a plurality of octaves of the equi-tempered musical scale, and a second group of pitch tracks thereon some at least of which are for the same frequencies as pitch tracks in the first group to supply notes lost at the points of division of said series of voicing representations, in combination with shutter means of wire-and-groove type, and wherein the grooves of said shutter means are interrupted in groups, with a passage of said shutter wires from grooves of one group to different grooves of the next succeeding group whereby to effect coupling, and in which certain of the series of voicing representations are common to less than the full number of said pitch tracks.

21. A pitch disc for use with a voice disc having divided series of voicing representations thereon and divided voicing shutters, said pitch disc having pitch tracks concentrically arranged thereon, said pitch tracks comprising a first group arranged successively in accordance with the semi-tones of a plurality of octaves of the equi-tempered musical scale, and a second group of pitch tracks thereon some at least of which are for the same frequencies as pitch tracks in the first group to supply notes lost at the points of division of said series of voicing representations, in combination with shutter means of wire-and-groove type, and wherein the grooves of said shutter means are interrupted in groups, with a passage of said shutter wires from grooves of one group to different grooves of the next succeeding group whereby to effect coupling, and in which certain of the series of voicing representations act to modify moving beams of light produced by pitch tracks on said pitch disc to provide voices having fundamental frequencies greater than the lowest fundamental frequencies derivable from their respectively associated pitch tracks.

22. A pitch disc having pitch tracks thereon divided into two groups, a first group of pitch tracks arranged consecutively in the order of the semi-tones of a plurality of octaves of the equi-tempered musical scale and a second group of pitch tracks not so arranged but including pitch tracks duplicating as to fundamental frequency certain of the pitch tracks in the first group, in which the pitch tracks of the second group lie concentrically inside the pitch tracks constituting the first group.

23. A pitch disc having pitch tracks thereon divided into two groups, a first group of pitch tracks arranged consecutively in the order of the semi-tones of a plurality of octaves of the equi-tempered musical scale and a second group of pitch tracks not so arranged but including pitch tracks duplicating as to fundamental frequency certain of the pitch tracks in the first group, in which the pitch tracks of the second group lie concentrically inside the pitch tracks constituting the first group, and in which a pair of additional tracks is arranged concentrically outside the first group of tracks, one of said additional pitch tracks constituting a speed control track and the other a vibrato track.

24. A voice disc for use with a rotating pitch disc having concentric pitch tracks, said voice disc having voicing representations thereon responding to the several pitch tracks and arranged in series traversing the said pitch tracks, where at least one of the said series of voice representations is divided intermediate its length into a plurality of groups of voice representations for different voices.

25. A voice disc for use with a rotating pitch disc having concentric pitch tracks, said voice disc having voicing representations thereon responding to the several pitch tracks and arranged in series traversing the said pitch tracks,

where at least one of the said series of voice representations is divided intermediate its length into a plurality of groups of voice representations for different voices, and in which certain at least of said series traverse less than the full number of said pitch tracks.

26. A voice disc for use with a rotating pitch disc having concentric pitch tracks, said voice disc having voicing representations thereon responding to the several pitch tracks and arranged in series traversing the said pitch tracks, where at least one of the said series of voice representations is divided intermediate its length into a plurality of groups of voice representations for different voices, and in which said last mentioned series contain voicing representations acting to increase the fundamental frequencies of cyclical variations produced in light beams traversing them at given speeds.

27. In a photoelectric generator of the type having a wire-and-groove shutter arrangement including a shutter plate, a voice disc supported by said shutter plate and closing the grooves therein, a pitch disc rotatively mounted on said shutter plate and driven with respect thereto, series of voicing representations on the voice disc traversing the pitch tracks, and voicing shutters acting to select voices, and an interconnection between wire portions traversing different ones of said grooves.

28. The structure claimed in claim 27 wherein certain of the grooves traversed by interconnected wire portions lie opposite pitch tracks for the same fundamental frequency on said pitch disc and wherein certain at least of the series of voice representations are divided into different voices intermediate their lengths at the points of occurrence of said duplicated frequencies.

29. The structure claimed in claim 27 in which the grooves in said shutter plate are interrupted and in which the interconnected wire portions are continuations of the same wire elements, said wire elements passing from groove to groove in the areas of interruption of said grooves whereby to effect coupling.

30. In a keyboard instrument having a bass section and a treble section, a photoelectric generator of a type having a rotating pitch disc, a voice disc and a grooved shutter plate with wire elements for covering and uncovering apertures therein, the voice disc having voicing representations, and the voicing representations and the apertures of said shutter plate being arranged in corresponding series traversing the pitch tracks, certain at least of said voicing representation series being divided intermediate their length into treble and base portions, the shutter wires traversing said portions being connected respectively to the bass and treble sections of the playing elements of said instrument.

31. The structure claimed in claim 30 wherein said instrument is a single manual instrument and wherein the bass and treble portions of the playing elements of said instrument are divided portions of said manual.

32. The structure claimed in claim 30 wherein said instrument has a manual and a pedal clavier and wherein the treble shutter wires are connected to the playing keys of said manual, and the shutter wires of the bass section are connected to the pedals of said pedal clavier.

33. The structure claimed in claim 32 wherein the grooves of said shutter plate are interrupted intermediate their lengths and in which the shutter wires pass from groove to groove in the areas of interruption to provide coupling.

34. The structure claimed in claim 32 wherein the grooves of said shutter plate are interrupted intermediate their lengths and in which the shutter wires pass from groove to groove in the areas of interruption to provide coupling, and in which certain of the series of voicing representations are common to less than the full number of said pitch tracks.

35. The structure claimed in claim 32 wherein the grooves of said shutter plate are interrupted intermediate their lengths and in which the shutter wires pass from groove to groove in the areas of interruption to provide coupling, and in which certain at least of the last mentioned series contain voicing representations for producing a fundamental frequency higher than the lowest frequency obtainable from the pitch tracks with which they are associated.

36. In a photocell musical instrument having at least two manuals and a pedal clavier, a pair of photoelectric generators each having shutters on a stationary shutter plate, and a rotating pitch disc with pitch tracks thereon, said shutters being divided into two groups, a first group for providing the semi-tones of a plurality of octaves of the equi-tempered musical scale for one of the manuals, and a second group for providing a plurality of notes for the pedal clavier.

37. In a photoelectric musical instrument having at least two manuals and a pedal clavier, a pair of photoelectric generators each having shutters on a stationary shutter plate, and a rotating disc with pitch tracks thereon, said shutters being divided into two groups, a first group for providing the semi-tones of a plurality of octaves of the equi-tempered musical scale for one of the manuals, and a second group for providing a plurality of notes for the pedal clavier, said generators also having a voice disc with series of voicing representations thereon for imparting voices, certain at least of said series being divided intermediate their lengths to provide in connection with said pitch tracks voices for said manuals and other voices for said pedal clavier and voicing shutters for said respective portions connected respectively with stop tabs for said manuals and said pedal clavier.

38. The structure claimed in claim 37 wherein the shutter plate is provided with grooves responding in position to said tracks, wherein wire shutter elements lie in said grooves, wherein said grooves are interrupted intermediate their lengths, wherein said shutter wires pass from groove to groove where said grooves are interrupted, so as to attain coupling, and wherein grooves for certain of said pitch tracks are traversed by different wires in different parts, certain of said wires having connection to the playing keys of a manual and certain thereof having connection with said pedal clavier.

39. A pitch disc having pitch tracks thereon divided into two groups, a first group of pitch tracks arranged consecutively in the order of the semi-tones of a plurality of octaves of the equi-tempered scale and a second group of pitch tracks not so arranged but including pitch tracks duplicating as to fundamental frequency certain of the pitch tracks in the first group, in which a speed control track is arranged concentrically outside the first group of tracks.

40. A pitch disc having pitch tracks thereon arranged consecutively in the order of the semi-tones of the equi-tempered scale and a speed

control track, thereon arranged concentrically with said pitch tracks.

41. In a photoelectric musical instrument of a type having a rotating pitch disc with concentric pitch tracks thereon and a voice disc having several series of voice representations, the series being directed transverse the pitch tracks, voicing shutters for said series, one of said series being an extension of the voice of another series, the voicing shutters for said last mentioned series being interconnected for simultaneous actuation.

42. In a photoelectric musical instrument of a type having a rotating pitch disc with concentric pitch tracks thereon and a voice disc having several series of voice representations, the several series being directed transverse the pitch tracks, one of said several series being an extension of the voice of another of said several series, said one series having a representation of a wave having substantially the same form but half the wave length of said other series.

43. In a photoelectric musical instrument including a pitch disc having a plurality of concentric circular pitch tracks, a shutter plate having a surface provided with arcuate grooves substantially responding to said pitch tracks in position, each of said arcuate grooves being a portion of a spiral, said spiral having a center off-set from the true center of said shutter plate, said shutter plate being recessed on that side having the grooved surface so as to interrupt said spiral, said shutter plate having light openings extending therethrough from said arcuate grooves, wires lying in said arcuate grooves, and means to actuate said wires so as to cover and uncover said light openings.

44. The structure of claim 12 in which a plurality of the said several series of voice representations lie in a given sector of said disc, the series making up said plurality being arranged parallel to one another, some of said parallel series being of different lengths whereby the angle defining said sector is smaller than would be the case if the said plurality of series were radially disposed of said disc.

45. The structure of claim 24 in which a plurality of series of voicing representations lie in a given sector of said disc, the series making up said plurality being arranged parallel to one another, some of said parallel series being of different lengths whereby the angle defining said sector is smaller than would be the case if the said plurality of series were radially disposed of said disc.

46. The structure claimed in claim 4 in which the rectilinear path assumed by a said shutter wire in passing through an ungrooved area from one grooved area to the next grooved area is a tangential projection of the shutter wire lying in an arcuate groove of the first mentioned grooved area.

47. A pitch disc having pitch tracks thereon divided into two groups, a first group of pitch tracks arranged consecutively in the order of the equi-tempered scale and a second group of pitch tracks not so arranged but including pitch tracks duplicating as to fundamental frequency certain of the pitch tracks in the first group, in which an annular armature rim is arranged about the periphery of said pitch disc.

48. A pitch disc having pitch tracks thereon divided into two groups, a first group of pitch tracks arranged consecutively in the order of the semi-tones of a plurality of octaves of the equi-tempered scale and a second group of pitch tracks not so arranged but including pitch tracks duplicating as to fundamental frequency certain of the pitch tracks in the first group, in which a tremolo track is arranged concentrically outside the first group of tracks.

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