Jan. 17, 1950 C. HOOK 2,494,943

PHOTOELECTRICALLY OPERATED ORGAN

Filed May 28, 1946 2 Sheets-Sheet 1

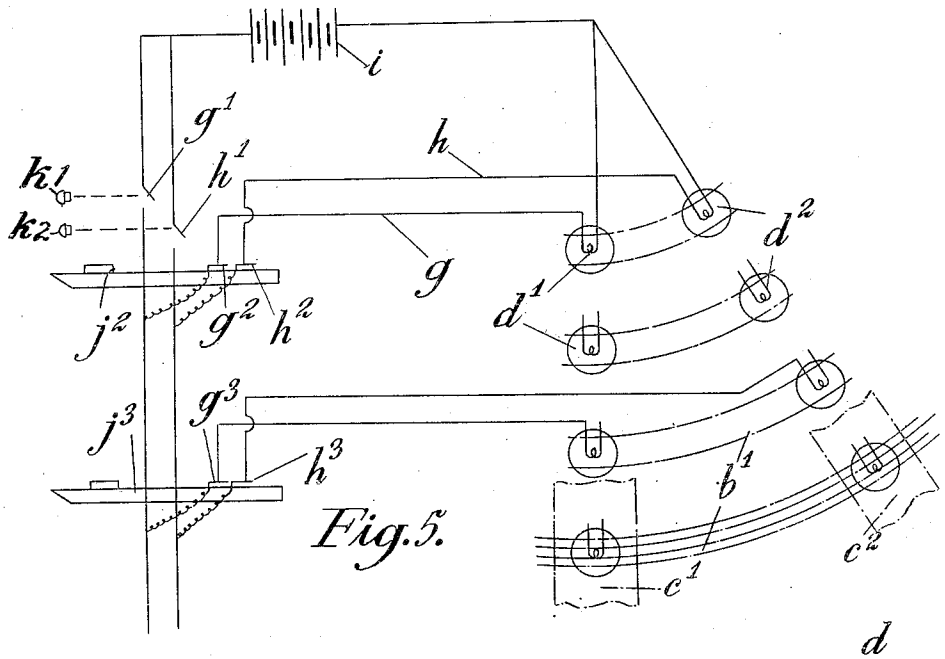


Fig. 5.

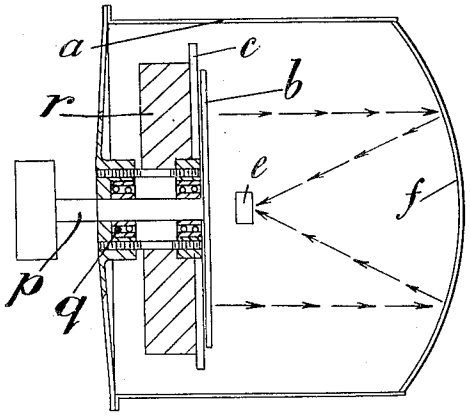


Fig. 1.

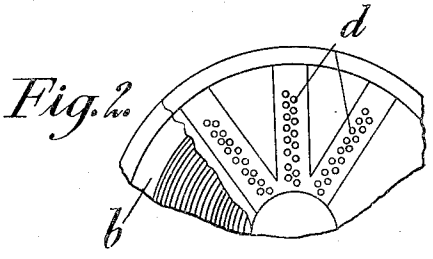


Fig. 2.

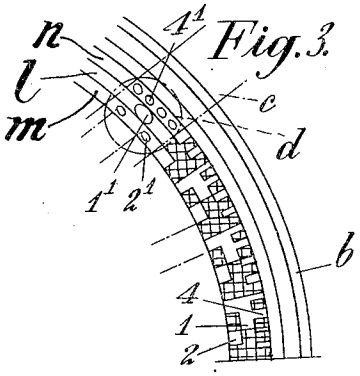


Fig. 3.

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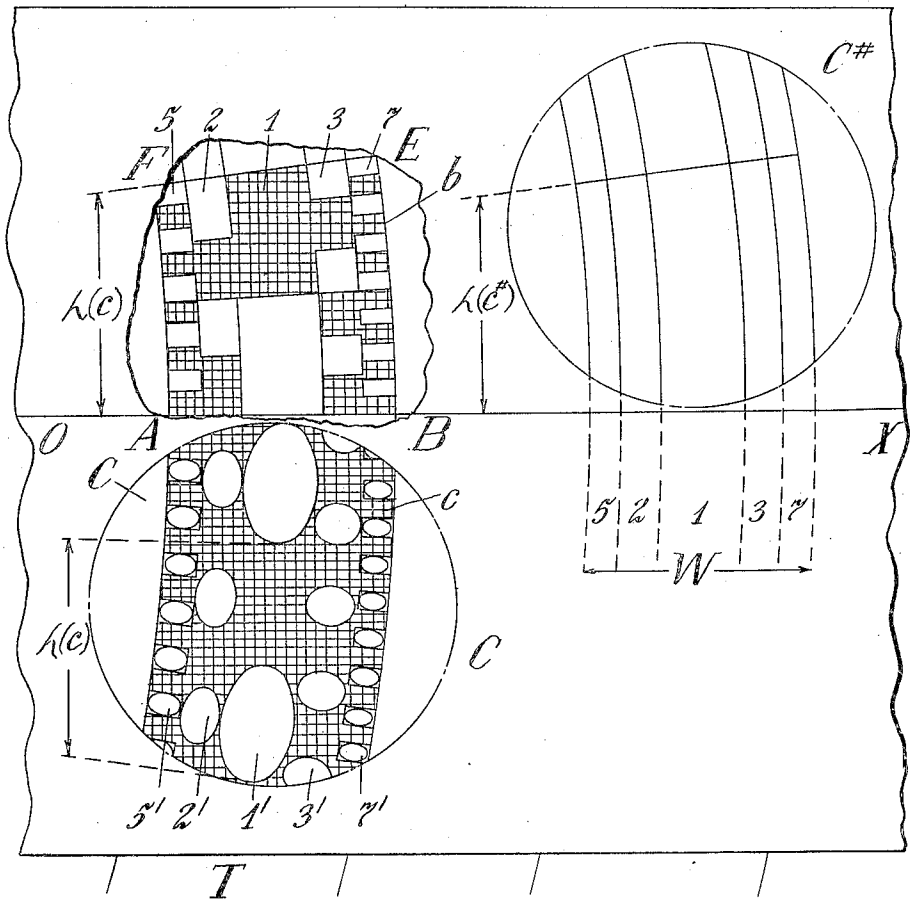


Fig. 4.

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UNITED STATES PATENT OFFICE

2,494,943

PHOTOELECTRICALLY OPERATED ORGAN

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Application May 28, 1946, Serial No. 672,745
In Great Britain June 4, 1945

3 Claims. (Cl. 84—1.18)

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This invention relates to improved means for the production of musical sounds more particularly suitable for musical instruments of the organ type.

Various means have hitherto been proposed for the production of such sounds comprising in combination: rotary discs on which simple forms of sine-waves are printed or cut; sources of light projecting their beams on the said discs; and photo-electric cells acted upon by the said beams under the control of the discs.

Tones of simple sine-wave forms do not possess satisfactory musical qualities and in order to obtain these, harmonics of the fundamental note have to be added thereto in various combinations and different strengths with respect to the fundamental. Attempts to carry this into effect in a practical construction by means of electrical couplers and resistances lead to an instrument which is costly to produce and difficult to maintain in order.

Moreover, if it is desired to increase the light flux given by a certain combination of fundamentals and harmonics, the current supplied to all the elements comprising that combination must be increased, and when it is desired to change the tone combination for that of another tone quality, a fresh set of harmonics must be selected and suitably dosed for strength. If the harmonics are borrowed from notes of the tempered scale (i. e. using the tracings intended for the fundamentals at a different register) taken higher up, then these harmonics are not true but false and the tones suffer in consequence.

The present invention, which is primarily directed to the production of a photographic disc wherein fundamental note frequencies and their true harmonics are provided by optical means, consists in sub-dividing the note tracings into independent tracings giving both fundamentals and a selection of harmonics of the same, side by side, and providing as large a number of fixed openings, in phase with the disc tracing, as can be conveniently placed in the space covered by light from a small electric lamp. The selection of harmonics to be combined with the fundamental for a given stop is obtained by selection of the corresponding openings in the fixed element hereinafter called the "light-filter."

The light-filter carries several openings per sub-track, each opening being placed in phase with the one before it on the same sub-track and in phase with the square openings on the disc behind. The amount of these in-phase openings depends only on the surface conveniently covered

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by the light from a light source. Thus the fundamental being of the longest wave-length will have only say two or three openings while the octave may have twice and the quint three times as many, and so on.

The openings in the light-filter are prepared in full on a master negative used to reproduce other light filters but in the prints taken from this negative a certain number of openings are blacked out in one type while others are blacked out in another type.

The selection of harmonics for a given "stop" is produced photographically on the light-filter device. For instance, in the preparation of a light-filter say for flute tone only the fundamental and the octave will be retained, all others being blacked out, it being known that this is the harmonic composition of flute tone. Again the number of openings remaining will vary the quality of flute tone and thus several different types of flute tones may be prepared. For other stops, e. g. clarinet, the selection will differ according to existing knowledge of the composition of musical tones and others may be found by trial and error.

By using the method according to the present invention, the necessity of employing any electrical couplings is eliminated and the stops correspond almost exactly to organ stops wherein each pipe has a fixed and unchanging tone quality.

Moreover, unlike in the case of an organ, each note can be varied in volume by varying the supply of light. This cannot be done with an organ pipe which must always have the same wind supply and, therefore, has always the same power. Furthermore, unlike other electronic instruments, the tone value for a given stop can be made to vary between treble and bass as is the case with instruments in the orchestra. This is done by blacking out certain harmonics more say in the treble and/or substituting other harmonics to change the tone quality in that part of the compass. It is well known that the tone of the orchestral flute gets richer towards the bass.

Both elements, disc and filter, are prepared from a photographic plate and the impressions are made with the aid of a machine of special construction. It is to be pointed out that on the disc the harmonics bear a definite relationship to their fundamental so that one fundamental wave, two octave waves, three quint waves, five fifth waves and seven seventh waves may all be taken together as one block. A larger number of harmonics may be used if required. We will call this "one complete wave length." First a com-

plete wave length of each note right across the disc is cut out of paper 10 or 20 times real size, the paper (red or black) having been first stuck onto a glass plate. In order that all cutting lines may be true radii a ruler is pivoted about the correct centre position and suitable marks are made for picking up the negative later on. Not all notes are cut onto the plate, only the odd numbers, thus leaving a blank space between each note. A second plate is cut carrying the even numbers and the same picking-up marks. These plates are lit up from behind and a photograph reduced to the correct size is obtained. (Photo on glass plate.)

This plate is now placed in the correct position in the lid of a revolving printing machine supplied with a large dial and pointer for the complete circle. The openings must be white on a black ground. Over each opening is a tube and an electric bulb of the flash lamp type wired to a key-board. The whole is made light-tight for working. View holes are supplied for picking up the markings on the negative and this work is done before the virgin plate is placed in the machine on the "table."

There are thus two such negatives to be worked onto the plate and the separations between notes determine the positions of the partitions between the lights. Actually the lights are separated by curved partitions, the curves following the circular tracks and there are several lamps wired in parallel for each note, the box forming $\frac{1}{10}$ of the circle and being shaped like a sector without the apex.

The first operation is not to go right round the circle which would be too long and contain too many operations, but to do say ten wave lengths in the lower octave and twenty in the upper. Thus after printing this negative and inversing, the negative performs 10 operations in the bass and 20 in the treble for one printing operation. The "stations" for corresponding notes in each octave are the same.

The sine-wave openings are prepared in a similar manner and if desired the photographic reduction may be done twice, even three times, so that the work to be done by hand is enlarged very considerably.

It will be seen that fixed elements can be changed one for another under a given rank of lamps.

In the accompanying diagrammatic drawings,

Figure 1 shows the general arrangement of that part of the apparatus in which the invention is incorporated, being a sectional view at right-angles to the plane of the discs;

Figure 2 shows a portion of the light filter in association with the small electric lamps;

Figure 3 shows, by way of example, a portion of the revolving disc with its various tracks associated with the corresponding tracks of a portion of the light-filter;

Figure 4 is an illustration of another example, on an enlarged scale; and

Figure 5 is a diagram of electrical connections.

Referring to Figures 1 and 2, *a* is a casing within which there is mounted the rotary disc *b*, the fixed filter *c*, radially arranged ranks of small electric lamps *d* and a photo-electric cell *e* onto which the fluctuations of light are focussed by a parabolic reflector *f*. *p* is the rotatable shaft upon which *b* is mounted, and *q* represents the bearings in which the shaft turns. *r* is the housing for the lamps *d*.

Referring to Figure 3 showing part of the revolving disc *b*, and stationary filter *c*, the tracing is sub-divided into three separate tracks *l*, *m*, and *n*, of rectangular openings for the passage of light, **1**, **2**, **4**, respectively representing the fundamental, the octave and double octave, and the light-filter is correspondingly provided with sine-wave openings **1'**, **2'**, **4'**, in phase with the rectangular openings in the revolving disc.

Referring to Figure 4, the separate tracks of rectangular openings **1**, **2**, **3**, **5** and **7** in the revolving disc *b* represent respectively the fundamental, the octave, the quint, the 5th and 7th harmonic and the light-filter *c* is correspondingly provided with sine-wave openings **1'**, **2'**, **3'**, **5'** and **7'** in phase with the rectangular openings in the revolving disc.

In this figure, which shows the first two notes C and C♯ of a radial register drawn on a greatly enlarged scale, the line OX represents a true radius. Assuming the part AB is the starting point for printing the track T for the note C, if AB produced towards X is also the base line for C♯, then the angular measurement λC limits the extent of the note pattern ABEF, hereinafter called a "note-wave," and likewise, $\lambda C\sharp$ limits the note-wave length for the next note C♯.

Now the length of λC is determined by the circumference divided by the frequency allotted to C and this applies to all the notes of the scale. In theory the frequency numbers should progress according to a geometrical progression based on $\sqrt[12]{2}$, the formula being $y=a\times(\sqrt[12]{2})^x$; however, in practice this would require fractional numbers which are impossible in a finite space. Therefore the frequency numbers must be chosen fairly high, say above 70 for the lowest note on the disc so that the supression of a whole unit, or rather the fixture to the nearest whole unit will differ only slightly from the calculated frequency figure.

It will be seen that the wedge shaped figure ABEF contains a regular pattern of width W (see C♯ figure) and length λC in the circumferential direction. The harmonics have been indicated only in the C♯ track. The number of extra harmonics that can be placed depends on the space and the scale at which the work is done.

The chain-dotted circle C represents the circular portion of the fixed light-filter that can be conveniently illuminated by a parallel beam of light from a small bulb of the flash lamp type, the light falling on such of the sine-wave openings as have been provided for that particular stop.

For different types of tone quality different lines of sine-wave openings in the fixed filter will be either totally or partially blacked out. For certain stops the openings blacked out may be varied slightly in the compass to imitate more perfectly certain orchestral instruments such as the flute which have different harmonic make-up in bass and treble registers.

Generally the blacking out will be done on the inverted negative of the fixed filter plates and will proceed by trial and error as with organ pipes.

The system described has the advantage of providing perfect harmonics for each note and not borrowed ones from the tempered scale.

Referring to Figure 5, d^1 and d^2 are two of the radial ranks of small electric lamps lit up selectively, e. g. for flute and clarinet, by being included in separate electric circuits *g* and *h* receiving current from a battery *i*. The circuit *g*

includes a switch g^1 operated by a stop knob k^1 for flute and switches g^2, g^3 respectively operated by keys j^2, j^3. Likewise the circuit h includes a switch h^1 operated by a stop knob k^2 and switches h^2, h^3 respectively operated by the same keys j^2, j^3.

The two ranks of lamps are, of course, associated with different light filters for flute and clarinet respectively; these are indicated by the dot-and-dash lines c^1, c^2. The sub-divided tracings of the revolving disc are indicated by the dotted lines b^1.

Since the whole of the harmonic selection is done by the choice of light filters, all that is necessary is to connect the scanning batteries to the keys in any desired numbers and to vary the strength of the current from each battery at will.

The details for carrying the invention into effect may be modified without departing from its scope.

I claim:

1. A musical instrument more particularly of the organ type comprising in combination a rotary disc and a fixed light filter one of them provided with a number of concentric tracings of sine-wave light passages and the other with a corresponding number of concentric tracings of rectangular light passages, each of the said concentric tracings in both the rotary disc and fixed light filter covering a succession of complete wave lengths and each comprising a number of separate concentric tracks of tracings respectively representing a fundamental and its harmonics, the latter separate tracks of tracings in the rotary disc corresponding to the separate tracks of tracings in the light filter, the light filter also comprising separate radial sections in

which some of the light passages in the concentric tracings and their separate tracks corresponding to harmonics are obscured; small electric lamps for projecting their beams through the said disc and filter and each lamp being capable of covering with its beam at least one wave-length of a fundamental with its harmonics all of which wave-lengths have to be complete; and photo-electric cells to be acted upon by the said beams.

2. A musical instrument as claimed in claim 1, in which the tracings of fundamentals and harmonics on the revolving disc and light-filter are in the form of photographic transparencies.

3. A musical instrument as claimed in claim 1, further comprising batteries for supplying current to the lamps selectively by separate circuits including stop operated and key operated switches, whereby the photo-electric cell will be acted upon in accordance with the fundamentals and harmonics on the light-filters associated with the lamps which have been lit under the control of the stops and keys.

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