June 10, 1930. A. H. MARKS 1,762,449

APPARATUS FOR THE PROPAGATION OF MUSIC AND OTHER CORRELATED SOUNDS

Filed Jan. 13, 1927 3 Sheets-Sheet 1

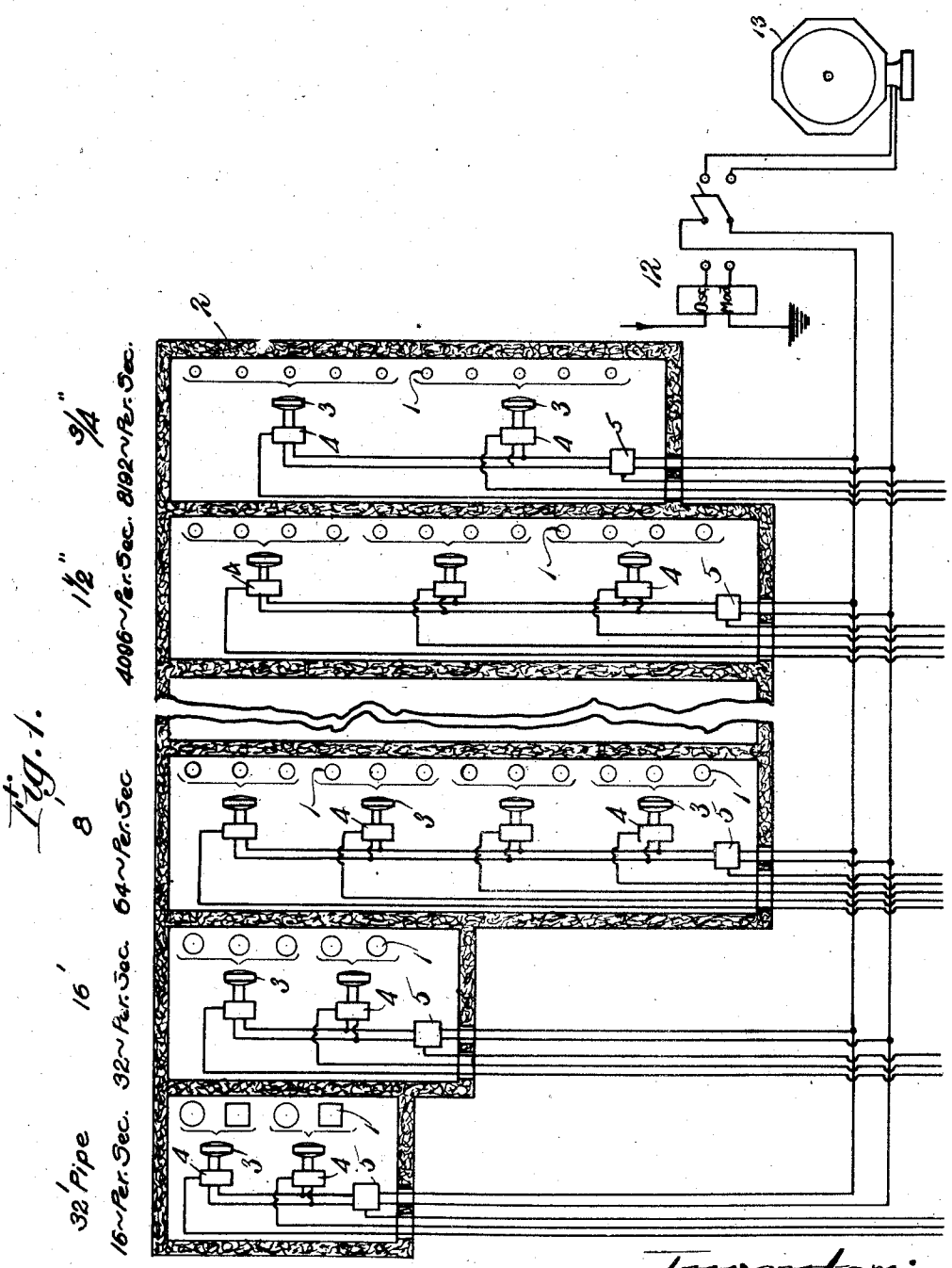


Fig. 1.

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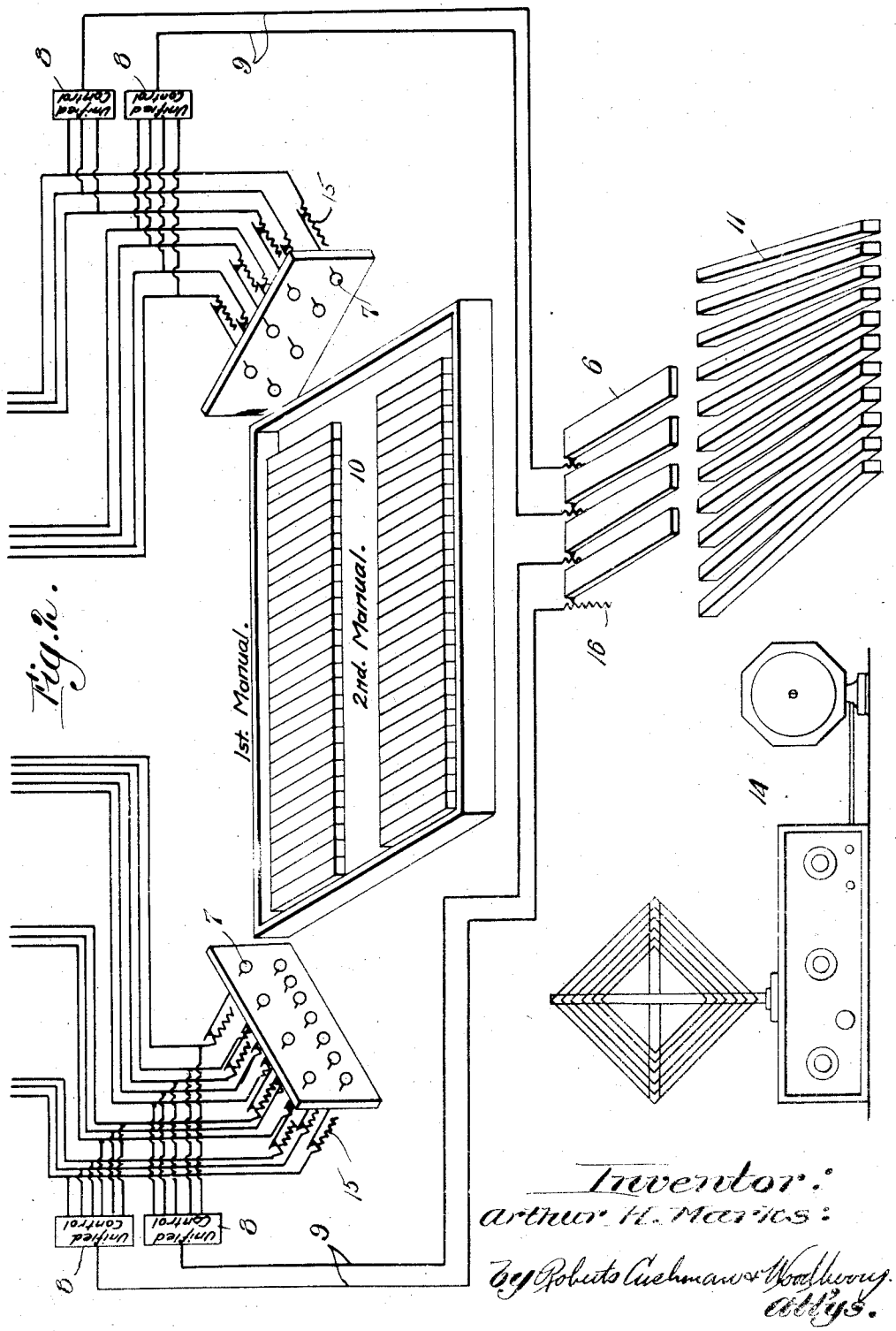


Fig. 2.

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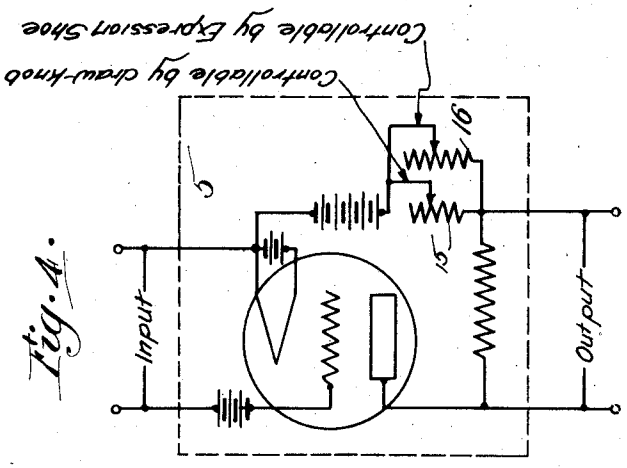


Fig. 4.

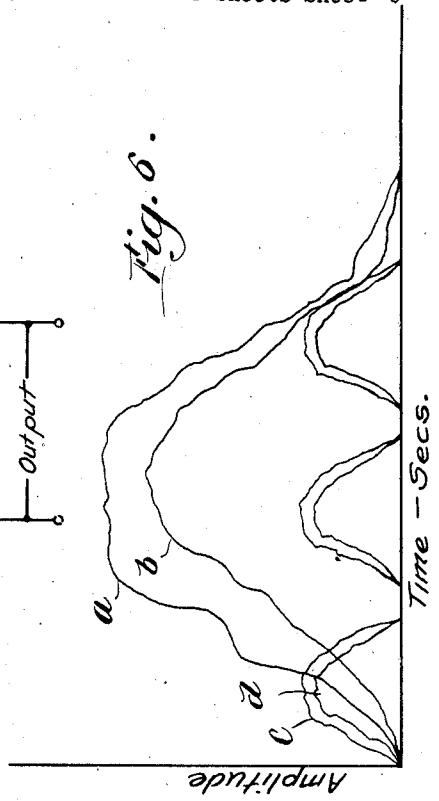


Fig. 6.

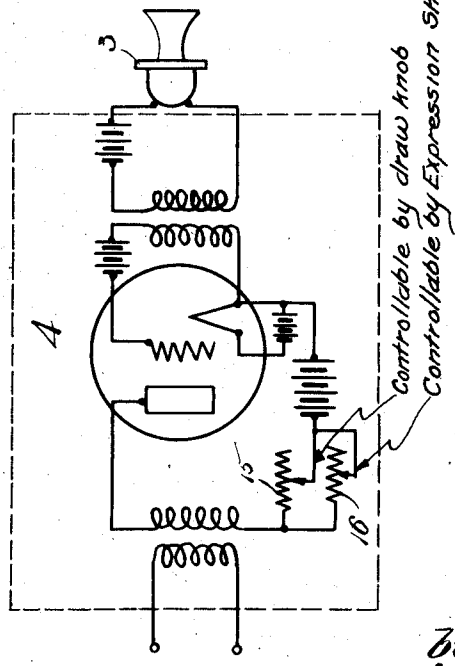


Fig. 3.

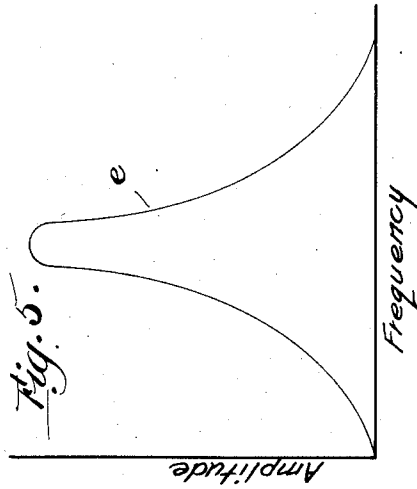


Fig. 5.

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Patented June 10, 1930 1,762,449

UNITED STATES PATENT OFFICE

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APPARATUS FOR THE PROPAGATION OF MUSIC AND OTHER CORRELATED SOUNDS

Application filed January 13, 1927. Serial No. 160,899.

My invention relates generally to the art of sound transmission and more particularly to apparatus wherein rare factions and condensations of a compressible medium are translated into electrical undulations for propagation by broadcast or wire connection to widely scattered or distant points. This energy is ultimately retransformed at the receiving station into sound impulses having characteristics approximating the original vibrations. However, the invention described hereinafter is directed more to the primary translation, i. e. the change in energy from acoustical to electrical and contemplates the faithful representation in the form of current undulations of the various combinations of sound waves emitted by the original source. Now, it appears that the difficulties attending the dissemination of music by broadcast have centered largely about the primary translation and in particular to the process of converging into one or more receptive means, the acoustical effect of the many tone combinations and characters. This means ordinarily comprises several microphones placed externally to the instrument. Under these conditions, the diaphragm, usually a flexible member, is constrained to vibrate either at a frequency falling within an extremely wide range or at a combination of several of these frequencies; in any case, the movement of diaphragm may only approximate the wave form of the impinging sound impulse. These difficulties are enhanced in the case of a pipe organ which ordinarily has extensive lay-out and is exceedingly rich in the various tone colors, pitch and volumatic changes, each offering a particular problem individually and collectively, to the satisfactory transmission of musical renditions.

In the matter of volumatic change, usually effectuated by shutters under the control of pedals and/or draw-knobs, it is apparent that microphones placed externally to the instrument are incapable of accurately registering the total range of manifestations portraying expression, moreover, the baffle method of controlling sound intensity is not without distortion and in the case of large organs, the extensiveness of structure necessary to operate the shutters adds greatly to the bulk and expense of the instrument, and tends to reduce the dependency of operation. In considering distortion, one must not overlook the fact that there is ever present attenuation of the electrical wave output whether propagated through wire or by radio, the effect of which is to favor certain frequencies such that the subtleness of notes having complex tone character is often obliterated during the process of transmission.

In order to further the favorable reception of organ recitals or renditions, I propose to adapt the present day organ to the peculiar needs of electrical transmission over great distances and particularly broadcasting. The modification of structure takes the form of a substantially complete acoustical isolation of the various stops along a demarcation of frequency and also of effecting total or partial separation of the various tones by positioning each of a number of microphones in certain relation to the stops sounding at a definite frequency. It will be at once apparent that the presence of substantially sound proof compartments lends the structure readily to electrical amplification individual to any number of stops and as offering convenience in the control of volume from the console and a simplification of the instrument as a whole. Furthermore, by providing as far as possible the usual arrangement of manuals, stops, pedals and other accessories familiar to an experienced organist, I achieve the desirable features in a modified structure without necessitating considerable transposition by the player.

The arrangement of stops in enclosures makes for greater efficiency in the translation of energy from acoustical to electrical due to the utilization of the total energy available and in addition, furnishes a unique method of erecting an acoustical barrier between the organist or performer and his music rendition. By providing a receiver nearby that registers the synthetic electrical effect of the various stops either

at a distant receiving station or prior to transmission, the organist is the better able to judge as to the proper place and amount of expression or other effect in order to render an accurate interpretation of a musical work to the distant audience.

Accordingly, the primary object of my invention is to improve the art of music transmission in general. A more specific object is to provide means for efficiently converting sound energy derived from a number of sources and distributed over a wide area, into the electrical equivalent for transmission and subsequent reproduction of the original sound aggregate.

Another object is to procure at a distant point, the highest possible degree of fidelity of the original rendition. A still further object is to simplify the organ structure without disturbing in appreciable measure, the usual arrangement of console accessories. Further objects and features will be evident from the perusal of the following description when considered in connection with the accompanying drawings in which like reference characters represent corresponding elements throughout the several views.

Fig. 1 represents a section in plan of a typical organ and by diagram, a number of receptive means with associated circuits adjacently disposed to the array of stops or speakers;

Fig. 2 is a continuation of the preceding view and shows partly in perspective and partly diagrammatic, the manual controls or console;

Figs. 3 and 4 illustrate a desirable mode of amplification;

Fig. 5 represents the characteristic curve of a certain diaphragm showing the phenomenal change in amplitude at the natural frequency period; and

Fig. 6 indicates broadly the wave form of a few more common sounds emanated during a rendition of average compass.

Referring particularly to Fig. 1, numeral 1 designates a number of pipes, stops or speakers comprising the usual tone families found in a representative organ. As will be understood, upon the application of air under pressure, these stops are designed to speak at regularly established frequency intervals from 16 cycles per second emitted by the 32′ pipe to 8192 cycles per second in the ¾″ stop and even higher. From these figures it will be apparent that in proposing the faithful translation of the various sounds into current undulations, the tremendous range in frequency presents a problem of no little import. Nor is this all, for in the organ of average size, the tone character or timbre of the individual stops may vary all the way from the squeaky little flute to the thunderous bass bourdon presenting a total variation in character quite beyond the capacity of a single diaphragm. In order to care for this extraordinary range of frequency and timbre, I first divide the various stops into a number of groups according to their predominant frequency. In making this segregation, it is probable that considerable compromise may be necessary in the case of pipes, the frequencies of which do not conform exactly to the arbitrary line of division. These groups are then acoustically separated from each other by partitions 2 comprising inelastic, sound absorbing, non-resonant substance as sheet asbestos, plaster, cloth layers or the like. In the compartments thus formed, there is placed a number of microphones or other receptive means having an electrical output in common for convenience of transmission.

While it is recognized that particularly good results are obtainable by providing each stop with an individual microphone having special adaptation thereto, this structure being specifically embraced by my invention, I have found that satisfactory reproduction is quite feasible with a reduced number of sound receivers. Having effected a division of stops on a predominant frequency basis, those in each compartment are then arranged in a gradation of wave character as determined electrically by oscillograph or other method. Each graduated series, the components of which sound at approximately the same frequency, is then divided into a plurality of sub-groups having a number of speakers determinable by the maximum latitude of character falling completely within the response range of a single vibration diaphragm. In arranging the sub-divisions, the difference in distance between the centrally disposed receptive means and the nearest and farthest removed stop must be considered; the smaller the difference, the greater will be the fidelity of response in the receptive means. Taking into account the range of tone character and difference in the spacial relation of adjacent speakers with respect to a given diaphragm, it will be apparent that as progression is made toward the lowermost frequency, the number of stops per microphone should decrease. Thus, in Fig. 1, this condition is exemplified by illustrating one microphone within response range of five stops sounding at an 8192 cycle note, while at the other end of the frequency scale a receptive unit accommodates only one or two pipes. The necessity for the change in the proportion of stops per mircophone is illustratively emphasized in Fig. 6, wherein curves *a* and *b* represent the sum total of fundamental frequency and overtones forming the characteristics of two representative notes sounding at approximately the same fundamental in the low portion of the scale. Curves *c* and *d* likewise apply to stops speaking at

the upper portion of the musical range. From an inspection of these graphs, it will be seen that the net effect of the overtones in shaping the character of sound is more pronounced as the frequency is diminished or length of pipe becomes greater; this fact is strikingly brought out by the difference in areas between the sets of curves.

Furthermore, in adapting a microphone by design to a note or group of same, it is preferable for well-known reasons to remove, as far as possible, the resonant peak inherent in the diaphragm and associated parts as shown in Fig. 5 from that of the predominating frequency in the particular note or group. The material and dimensions of the diaphragm also should be such as to allow a movement closely approximating the curve enveloping the character aggregate of the notes within the range of response. In short, each microphone must have adaptation to its individual load. While directions concerning the relative positions and adaptations of the microphones seem more or less precise, it is to be understood that in the absence of an enclosure for each stop which may prove impractical from either of an acoustical, structural or cost standpoint, the theoretical determinations call for modification in practice due in part to substantial merging of portions of microphone response areas. However, considering the musical effect as a whole, I have found that the stated methods of arranging the stops with respect to a smaller number of microphones effectuates a decided improvement in quality of tonal output.

Now, as stated hereinbefore, I propose to electrically amplify the note issuing from each stop or a group of same, eliminating the necessity for shutters and for this purpose, provide a number of devices diagrammatically represented by rectangles 4. These devices which may or may not be individual to the microphones, take the form of the audion, well known for its distortionless amplification, and associated input and output transformers as shown in Fig. 3. By rectangle 5, the contents of which are illustrated in Fig. 4, I show another form of audion circuit which is applicable to the last stage of amplification within each compartment. Inasmuch as the exact nature of the amplifiers is self-explanatory and known to the art, a lengthy description of the same appears unnecessary. Suffice to state, that the amplification ratio of both types of audion system is controlled with suitable means by the familiar expression shoes 6 and/or draw-knobs 7 at the console. This means may take the form of variable resistances effectively inserted in the plate circuit of each audion and conveniently controlled from the console by a mechanical and/or electrical system of linkage. The pair of resistances 15 and 16 should be preferably of a coarse and fine gradation controlled by draw-knobs 7 and expression shoes 6 respectively in the manner shown. If desired, instead of utilizing two resistances, one may limit the function of the draw-knob to a make and break circuit arrangement to merely energize or de-energize the amplifiers, in fact, many arrangements for controlling the latter are readily adaptable. By rectangle 8, I indicate any well-known switching arrangement whereby the current passing through a circuit diagrammatically indicated by single conductor 9 may effectively control any one or all of the electrical connections passing out from the rectangle.

It is to be understood that manuals 10, pedals 11, and draw-knobs 7 each have their usual air control function, while the latter may take on an additional function and with the expression shoes regulate either, jointly or severally, the amplification of the various tone characters. Moreover, it will be obvious that my invention is not limited to the thermionic amplification structure shown or to the described mode of operating same as various modifications will suggest themselves to those skilled in the art. However, by reason of its faithful translation, compactness, simplicity and lending itself readily to a multi-unit system, the audion appears to have considerable advantage over other types of amplifiers known to the present art.

As indicated in Fig. 1, the combined output of the microphones and amplifiers may be passed through a broadcasting train represented by rectangle 12 to an antenna or if desired, may be immediately reconverted to the acoustical state by one or more reproducing devices 13.

Now, inasmuch as the pipe array is enclosed in a sound-proof chamber, the organist or performer receives no direct auditory effect from the primary rendition. By employing receiver 14, he is enabled to obtain by localized radio transmission a secondary rendition by which to judge the musical synthesis at the distant receiving station and if necessary, correct any deficiencies of effect. The subject matter last mentioned is disclosed and claimed broadly in my Patent No. 1,596,984, granted August 24, 1926, and entitled "Method and apparatus for broadcasting."

From the foregoing, it will be apparent that in the proposed instrument, as modified, the tremendous range between the grandeur of the full organ and its softest voice representing a complex and ever varying proportion of tone color, frequency and volume is preserved in marked degree during the primary translation process.

While exemplifying my invention by application to a pipe organ, it would seem that the disclosed subject matter may be embodied in many other forms than those shown and described, and I therefore impose no limitations of structure on the invention except as may be implied from the scope of the appended claims.

I claim:

1. In an instrumentality for producing sounds of various frequencies and complex characters, a plurality of sound-proof compartments, each containing a group of speakers sounding at approximately the same fundamental frequency, each group being arranged in a gradation representing variations of tone or timbre.

2. A pipe organ comprising speakers arranged in a plurality of groups, each containing stops sounding approximately the same frequency but varying in timbre and means for selectively translating into electrical energy the acoustical effect derived from a certain number of stops in each group less than the whole group.

3. A pipe organ comprising at least one stop of each tone family desired enclosed in an acoustically isolated chamber, each chamber provided with one or more microphones for translating the sound impulses into current undulations.

4. A pipe organ comprising at least one stop of each tone family desired enclosed in an acoustically isolated chamber, each chamber provided with one or more microphones connected to an amplifying device for translating the sound impulses into amplified current undulations.

5. A pipe organ comprising at least one stop of each tone family desired enclosed in an acoustically isolated chamber, each chamber provided with one or more microphones connected to an amplifying device for translating the sound impulses into amplified current undulations and means located on console for both controlling the operation of each stop and amplifier.

6. A pipe organ comprising at least one stop of each tone family desired enclosed in an acoustically isolated chamber, each chamber being provided with one or more microphones for translating the sound impulses into current undulations, each microphone being particularly responsive to a predetermined range of frequencies.

7. The method of adapting a pipe organ to efficient transmission of music which comprises dividing the speakers along a frequency demarcation and selectively translating into electrical energy the acoustical effect derived from each division of speakers.

8. The method of adapting a pipe organ to efficient transmission of music which comprises effecting an acoustical isolation between groups of stops, arranging each group in a gradation of stops representing variations of tone, and selectively deriving the tonal output of a predetermined number of stops in each group.

9. The method of adapting a pipe organ to efficient electrical transmission of music which comprises effecting an acoustical isolation in substantial degree between groups of stops, and selectively translating into undulations of current the acoustical energy derived from one or more stops in each group.

10. The method of adapting a pipe organ to efficient transmission of music which comprises dividing the speakers along a frequency demarcation, selectively translating into electrical energy the acoustical effect derived from each division of speakers and controlling the volume of the energy so transmitted from each division.

Signed by me at New York city, N. Y., this 6th day of January, 1927.

ARTHUR H. MARKS.