
(a) Here insert (in full) name, address, and nationality of applicant or applicants (including the actual inventor).

## PATENTS \& DESIGNS ACTS, 1907 to 1932.

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## APPLICATION FOR PATENT.

## 10516

6 APR 1934
do hereby
declare that I am (or we are) in possession of an invention the title of
(b) Here insert title of invention.
(a) I (or We) Lev $\sqrt{\text { roland }}$
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(1) Where application is made through a Solicitor, Patent Agent, or authorised representative.

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PATENTS \& DESIGNS ACTS, 1907 to 1932.

PROVISIONAL SPECIFICATION. (To be furnished in Duplicate.)
(a) Here insert title
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6 APR 1934
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(a) $\qquad$
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do hereby declare the nature of this invention to be as follows :-
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The invention concerns a method for registering sound, for instance speech or music by photographic methodsflgie a strip of film, and reproducing it for instance by sending light through the film and using a photocell to convert the variations of light into sound.
Figure 1 illustrates the principle of the invention. 5 is a film on which speech or music is registered by a new method which will be described further below. This film moves slowly past the slit 4, and the light admitted to the photocell 6 has to pass not only slit 4 and that section the film 5. which is in front of slit 4 , but also a quickly moving film 3, in the sound generator, which is continuously revolving in and itself passing in front of slit 4. An optical lense 2 makes the light of the light source lo parallel and throws it across the sound generator film 3 the slit 4 and the modulator film 5 on the photocell 6. Whereas the sound generator film 3 is always the same for every piece of music or speech, the modulator film 5 carries a record of the individual piece of speech or music which is to be reproduced.

$$
\text { In figure } 2 \text { you see two strips of the films } 5 \text { and }
$$

 The upper film strip 5 is the modulator film. The section $\Delta y$ which is in front of the slit 4 corresponds to a period of time of $1 / 10$ to $1 / 40$ th of a second, that is to say that in $1 / 10$ to $1 / 40$ th of a second the
section $\triangle \mathbb{y}$ passes the slit 4, and after that time a new section $\Delta y$ the modulator film will be in front of SIC the slit 4. This period of time (which may be $1 / 10$ th to $1 / 40$ th of a second) will be called the time basis of reproduction.
the If one goes within the section 4 y from 810
left tolfight across the film 5 one passes ll sections $\Delta X$ and the transparency of each section (the amount of lisht each section will allow to pass) determins the compoby the filmo 3 sition of the sound which is produced at the time when the section $\Delta X$ is in front of the slit 4. We have drawn 11 sections in order to simplify the drawing, but in reality the number of sections will at least be 200 or any number beyond that. If the number of sections $\Delta x$ is very large one gets a continuous curve by plotting the transparency of the film 5 as a function of x for a definite section $\Delta y$. Such a curve is shown in figure 3. It gives the frequency spectrum of the a certain.
sound at a definite moment( within basic period of time,
the Iime basis of the reproduction). $\boldsymbol{x}$ need not be a direct measure of the frequency, but the frequency is a function of $\mathrm{x}(\boldsymbol{x}=\boldsymbol{f}(\boldsymbol{x}))$ the form of which can be chosen to suit certain requirements. The film 3 in figure 2 is also divided into ll sections $\Delta x$ at $\left(x_{1}, x_{2}, x_{3}, \ldots x_{10}\right)$. Within each of these sections $\Delta x$ the transparency varies along the film as a sinus function of $y$ (transparency $=A(x) \sin 2 \pi \mu(x) y$.) $A(x)$ is a constant i.e. its value does not vary with $y$ (but it varies from one section $\Delta x$ to another, $A$ being a function of $x$. Of course $\mu$ varies also from one section $\Delta x$ to another, $\mu$ being a function of $x$. If the film 5 would remain fixed, aiven section $\Delta y$
being in front of the slit 4 ;and/the film 3 Wheule moved past the slit 4 with a velocity $v$ one would hear a. sound composed of 11 frequencies i.e. the frequencies $v_{*} \mu\left(\gamma_{1}\right) ; v_{1} \mu\left(\gamma_{2}\right) ; v \mu\left(x_{3}\right) ; \ldots v^{\prime} \cdot .\left(r_{1}\right)$, each of them with an intensity determined by the transparency of film 5 at the corresponding sections $x_{1}, x_{2}, \ldots x_{11}$. The individual values of the transparency for the corresponding sections $\Delta x$ can be seen from the curve in figure 3 . If film 5 did not move we would always hear one and the same sound composed of the said frequencies with constant intensities. However the film 5 is moving slowly so that after $1 / 10$ to $1 / 40$ th of a second another section $\triangle \mathrm{y}$ is in front of the slit 4 and we shall therefore hear a varying sound which is composed of the frequencies which are generated by film 3, each frequency having an intensity which is controlled by the transparency of the different sections of film 5. If we have a large numberof frequencies (a large number of sections $\Delta x$ ) we can get a very good reproduction of speech or music.

Figure 4 shows an example for recording intensities on the modulator film 5. Each section $\Delta x$ has a transparent section surrounded by two non-transparent sections. The amount of light transmitted by section $\Delta x$ is thus proportionate to the width of the transparent section which varies along the film, the width being a function of y .

Figure 5 shows another example for recording intensities on a modulator film 5. Here we have within each section $x$ a "transparent" section between two

## Page 4.

non-"transparent" sections. The breadth of the "transparent" section is constent along the film (agk does not vary with y ), but the "transparent" section is not completely transparent, its extinction varies along the film (is a function of $y$ ).

Both ways of recording used in figures 4 and 5 can be combined, if necessary, leading to a "transparent" section, the breadth and extinction of which veries along the film.

If the slit 4 has a width of $1 / 10 \mathrm{~mm}$. and the basic period of time of the reproduction is $1 / 20$ of a second the modulator film moves 2 mm per second i.e. for the reproduction of a piece of music, the performance of which lasts one hour, one will a film strip of the length of 7.2 metres. The same will hold if the slit 4 has a width of .05 mm . and the basic period of reproduction is $l / 40$ of a second. It is not necessary to use a slit 4, the width of which is constant across the film.

As shown in figure 6 the width of the slit 4 may vary with $x$, the slit being narrow at the right end where the high frequencies are controlled, and being wider at the left end where the lower frequencies are controlled. It has an advantage to use such a slit which makes the basic period of time smaller for the higher frequencies than for the lower frequencies.

The sound generator film 3 will in most cases be made with varying extinction along the film and used in combination with a modulator film of the type shown in figure 4.or5. It is, however, possible to reverse the
combination and use a modulator film of the type shown in figure 5, and a sound generator film where the transparency of each section $\Delta x$ is created by a transparent section within each section $\Delta x$; the width of the said transparent section varying with $y$. Of counse sic sound generator film off the first mentioned type can be used also in combination with a modulator film of the typotshown in figlure 5 .

It has been mentioned that the number of the sections $\Delta x$ will be large and can be anything above 200, for instance if the lowest frequency which we wish to include in the reproduction is 100 , and the highest frequency is 5,000 , and if we wish that the difference between two adjacent frequencies $\frac{\Delta \nu}{s h o u l d}$ be about $\Delta V=\frac{\nu}{100} ; i . e$. $1 \%$ of the frequency, we shall have to use about $N=\ln \frac{5000}{100} / \ln \left(1+\frac{1}{100}\right)$ frequencies. $\ln \frac{5000}{100}$ is about 4 ; $\ln \left(1+\frac{1}{100}\right) \cong 0,01 ; i, e . N \cong 400.10$ S10.
Figure 7 shows the usual arrangement of transforming the variations in the intensity of the light (that enters the photocell)into sound. 6 is a photocell, 71 its cathode which is connected through a high resistance 72 to point 73. Point 73 is connected through a condensor 74 to point 75 and point 75 is connected through a small resistance 76 to the anode 77 of the photocell 6. Point 75 is connected through a resistance 78 to the positive pole 79 of a high voltage battery 80. The negative pole 81 of this high voltage battery is connected through a small battery 82 to point 73 and to the glowing filament 83 of a valve 85. The grid 84 of this valve is c onnected to the cathode 7l of the photocell 6. The anode 86 of the valve 85 is
connected to one end of the primary 87 of a transformer 88 the other end of the primary being connected to point 89. Point 89 is connected through a resistance 90 to the 79
positive pole Q/of the high voltage battery 80 on the one hand and through a condensor 91 to the negative pole 81 of the same high voltage battery on the other hand. The secondary 92 of the transformer 88 is connected to an amplifyer set 93 which feeds the loud speaker 94.

Figure 8 shows another arrangement which serves the same purpose as figure l, namely the purpose of reproducing the sound recorded on film 5. 101 is a light source placed in the focus of the optical lense 102 which throws parallel light across the slit 104 and the sound generator 103. A second optical lense 107 projects the imace of the sound generating film 103 on the modulator film 105 and the light transmitted by 105 falls on the photocell 106. A transparent glass plate 108 diverts some light by reflection at its SIC. of the film 103 (in front of 104) surface and throws a faint image/through the dark filter 109 on the photocell 110. The pumpose the second photocell 110 is the following:

If, for the recording of sound on the modulator
film 5, the method indicated in figure 5 is used it is sometimes difficult to reach a very high extinction i.e. the transparency of the sections $\Delta \mathrm{x}$ has, though a very small, yet/finite value wwar in the absence of the coresponding frequencies.in thersouk which orght to roceried it be reproduced.
If the second photocell we not present weak light of all frequencies would reach photocell 106 in all circumstances, and would produce disturbing sounds. If one uses a

## Page 7.

second photocell 110, which gets light direct from the sound generator film, the filter 109 can be so adapted that the current generated by 110 should for every frequency compensate the current generated by 106 for the same frequency in case the transparency of the corresponding section $\Delta x$ of the sound modulating film 105 has its minimum value (which signifies the absence of the corresponding frequency in the music or spech recorded on film 105).

Figure 9 shows how the photocells 106 and
110 are used. $\quad 115$ is a high voltage battery, the positive pole 116 of which is connected to the anodes 117 of the cell 110 and the anode 118 of the cell 106 . The cathodell9 of the cell 106 is connected to point 120 and the cathode 121 of cell 110 is connected to point 122. The negative pole 123 of the high voltage battery is connected to point 124 which is connected to the positive pole 125 of a small batteryidthe negative pole 126 of which is connected to point 127. Point 127 is connected through a high resistance 128 to point 120 (which is connected to the cathode 119 of the cell 106), and point 127 is also connected through another high resistance 129 to point 122 (which is connected to the catiode 121 of the cell 110 ). Point 127 is connected through the condensor 130 to point 131 to which the positive pole 125 of the small battery 132 is also connected (through point 124). Point 130 is connected to the eathodes 133 of the valve 134 and 135 of the valve 136. The grid 137 of the valve 134 is connected to point 120 and the grid 138 of the valve 136 is connected to point 122. The anode 139 of the valve 134 is connected to the end 140
of the primary coil 141 of the transformer 142. The anode 143 of the valve 136 is connected to the other end 144 of the primary coil 141. The middle 145 of the primary coil 144 is connected to the positive pole 116 of the high voltage battery 115. The secondary 146 cam be connected to an amplifyer set and a loud speaker as described previously in figure 7.

If the recording of the sound on the modulator film 5 is performed in a manner indicated in figure 5 . one need not have a limited number of sections $\Delta \mathrm{x}$ which are isolated from each other by blackened strips 51, 52, 53 .... . Within each section $\Delta y$ the transparency of the film can be a perfectly continuous function of $x$. It has advantages to use such a "smooth" modulator film in combination with a "smooth" sound generator film. We can get "smooth" sound generator films in different ways:

Figure 10. gives an indication of a "smooth" sound generator film. A sinus function of a certain wave length is photographed on section $X_{1}$ of the film (ie. the transparency varies with $y$ along section $X_{1}$ according to $A(x) \cdot \sin 2 \pi \mu(x) y$ ); another sinus function of a $1 / u\left(x_{2}\right)$ slightly different wave length is photographed on section $x_{2}$ Section $\frac{\alpha_{1}}{\text { 有, and section }}$ figure 10. In the same way a third sinus function is photographed on section $\frac{1 / 3}{\frac{1}{4}}$, the wave length being again shifted a little against the wave length of section $\mathbb{R}_{2}$
 indicated in figure 10. If light is admitted by the modulator film at a definite very narrow section $d x$ at a

Page 9.
definite spot $x$ of the sound generator film, a sound will be produced which will contain a narrow band of frequencies, the centre of gravity of which will be determined by $x$. The breadth of the band depends on the breadth/of the sections $1,2,3 \ldots$, on the shiftgCf these sections with respect to each other, and on the shift of frequency $\frac{d \mu}{d x} \varepsilon$ from wa one section to another. The breadth of the (band produced by light transmitted at a definite spot $x$ will approximately be $\Delta \nu \cong v \frac{d \mu}{d x} \cdot \varepsilon \cdot \frac{D}{\varepsilon}=v \cdot \frac{d \mu}{d d} \cdot D$

8/6
If we wish to reproduce music it is important that the mean frequency $\bar{\nu}$ generated by light transmitted at a definite spot $x$ should be proportional to $e^{\alpha x}$ $\left.\frac{d \mu(x)}{d x}=\alpha \mu\right)$. If this condition is fulfilled $\left(\mu=c_{1} e^{\alpha x}\right)$
, a small shift of the modulator film with respect to the sound generator film in the direction $\not x$ of the $x$ axis will not distort the music but only change the key; for instance a fairly large shift would lead to the same music being played half a tone higher or lower. (It may be stated that our system of sound reproducing makes it possible to vary the tempi, by varying the speed of the modulator film without changing the speed of the sound generator film).

Figure 11 skate indicates a special type of a "smooth" sound generator film. The two lines 151 and 152 which are drawn parallel to the $x$ axis across the film define a section $Y_{g} \nexists$ of the film which corresponds to a certain length of time say $1 / 10$ to $1 / 40$ th of a second which we will call the basic length of time $\%$ of the sound generator film of this type. 1) The line 153 1) If $v$ is the velocity, at which the sound generators is moving, then $v_{*}+T_{g}=Y_{g}$
indicates the midale of the section $Y_{g} \% 8 / 0$ The transparency of the film in the section $\boldsymbol{X}_{1}$ is given by a. function $A\left(x_{1}\right) \cos \mu\left(x_{1}\right)\left(y-y_{0}\right) ;$ being $/$ the middle of section $7 / \bar{y} q$.
$\$ 10.0$.

This function is shown in figure lla.
The transparency of the film in the section $\boldsymbol{X}_{\mathbf{2}}$ (which is shifted in respect of section $\mathcal{X}_{\boldsymbol{i}}$ by $\mathcal{E}$, and is over lapping section $x_{i}$ ) is given by a function $A_{\left(x_{2}\right)} \cos \mu\left(x_{2}\right)\left(y-y_{0}\right)$
 function, is shown in figure 11b. The same applies to section $X_{3}$ and so on.

The next section $[/ g$ between 152 and 154 is made exactly alike the section/between 151 and 152; again all the functions copied within this section $\sqrt{6} / g$ have their maxima in the middle of the section 55. The same holds for tre every following section fog

The boundaries of the sections $Y_{g}$ need not be parallel to the x axis, but can have a slight slope as indicated in figure 12.

One can also have a basic length of time of the sound generator film which is a function of $x$ the time being larger for the lower tones than for the higher ones. This is indicated in figure 13. Figure 14 shows another method of registering sound on the modulator film 5. The transparency of the film varies continuously (as a continuous function of $x$ ) across the film. This is brought about by having nontransparent and transparent lines running at $45^{\circ}$ to the $x$ axis across the film, the breadth of the transparent lines being a function of $x$.

Methods will be described which make it

## Page 11.

possible to manufacture one of the above mentioned types of sound records on the modulator film. We shall assume that we have an ordinary record of a piece of music or of speech on an ordinary film, the sound being registered in one of the two usual types of registering.

- We shall describe methods for
transcribing this usual type of record into a sound record on the modulator film of one of the types mentioned above.

In figure 15a 160 is a film similar to the sound generator films as described above. 161 is the a piece of music or speech film on which/the staund is recorded in one of the two usual ways. Sle light emerging from the light source 162 placed in the focus of the optical lense 163 , is made parallel by the lense and thrown through a section $Y_{\boldsymbol{R}}$. of the sound generator film 160 and of the film 161. The length $Y_{\boldsymbol{R}}$ corresponds on the record 161 to a certain length of timet the basic/time of the operation of recording. (.... 810 , While a certainsection of the record 161 is in front of the window 164, the film record 161 being at rest, the film 160 which will be çalled the "analyser" is kept moving. The light transmitted by the section $\mathrm{Y}_{\boldsymbol{R}}$ of both films is collected by the lense 165 and thrown on the photocell 166. As shown in figure 15b the window 164 admits only light across a small section $d x$ of the analyser. By shifting the analyser in the direction of the x axis different sections $x$ can be brought in front of the window 164. For a given section/of the analyser (representing a given mean frequençid) in front of the window, and with the "amalyser" tine requingxa kept moving in the direction of the $y$ axis, while the film record 161 is at rest, the light
transmitted by the two films will have a varying intensity. The amplitude of the variation will be determined by the intensity of the oscillation having the frequency $\bar{\mu}(x)$ on the film record 161. Therefore the amplitude of the alternating current generated by the photocell 166 will be determined by the intensity of the oscillation alternating
$\bar{\mu}(x)$ on the film record 161. If theffeurrent generated by the photocell 166 is amplified and used to control the intensity of a light source 167, the light of which is thrown through a slit 168 on a section $d x$ of the film 169 the transparency of the section $d x$ will be determined by the intensity of the oscillation $\bar{\mu}(x)$ on the film record 161. By shifting the film 169 together with the analyser 160 parallel to the x axis, different spots $x$ of the analyser are brought in front of the slit and at the same time
164 tageknaskick/different spots x of the film 169 are brought in front of the slit 168. At each section $d x$ at the spot $x$ of the film 169, the intensity of the corresponding oscillation $\bar{\mu}(x))^{\prime}$ the film record 161 ẋs regixitan gets thus registered. 169 or negatives of it can be used as modulator film for our method of sound reproduction. The operation of transcription consists of the repetition of two alternative operations: the analyser 160 and the record 169 are together shifted forwards and backwards along the $x$ axis while the analyser is revolving fast and the film record 161 is at a stand still as well as the record 169. When ass axamex stan During this motion the film l6I is exposed to the light of the light source 167. The motion being completed, the film record 161 and the film 169 are moved along the $y$ axis by a length corresponding to a fraction for

Page 13.
instance $1 / 10$ of the basic length of ore
transcription operation (for instance 161 is shefted moved along by $1 / 10$ of $Y_{R}$ ). Then 161 and 169 are again shifted forwards and backewards parallel to the x axis while the light source 167 acts on the film 169 and so on.

The current generated by the photocell 166 is amplified in the same manner as shown in figure 7 , the only difference being that the loud speaker in figure 7 is replaced by a suitable light source for instance a cathode tube with luminescent screen. In figure 16.175 is a Brown tube. The electrons emitted by the filament 176 are controlled by the cylinder 177 to which is connected negetive pole lig8 of a small battery 179, the positive pole 180 of which is connected to the secondary 181 of a transformer 182. The other pole of the secondary 181 is connected to the 183 cathode 176, the primary/of the transformer being connected to the amplifyer shown in figure 7. The two ends of the filament 176 are connected to the poles 184 and 185 of the heating battery 186, and the pole 185 is connected tothe pole 187 of the high voltage battery 188. The positive pole 189 of the said high voltage battery is connected to the anode 190 of the tube 175. 191 is a luminescent screen emitting light under the influence of the cathode rays, the intensity of the light being controlled by the amplitude of the alternating current generated by the photocell. The tube 175 acts as rectifyer in the same way as an audion. The battery 179 is maintaining $\overline{\text { maxkumixmm such a voltage }}$ at the "grid" 177 that one half cycle should get surpressed.

[^0]will be described which only makes use of photographic methods. In figure 17. 200 is a light source placed in the focus of a lens $\neq 201$ projecting parallel light on the analyser 202 and on the section $Y_{R}$ of the film 203 on which the piece of music or speech recorded in one of the two usual ways of recording. A cylindrical lense 204 concentrates the light transmitted by 202 and 203 on a small section dy of a film 205, which will be called the first intermediary film. The light of each section $d x$ of the film 203 will be concentrated on the corresponding section $d x$ of the first intermediary film. The films 203 and 205 are simultaneously moved through the apparatus, both films moving for instance at the same speed. A given section $d x$ of the film may 205 show after being developed an extinction as indicated in figure 18. The period of oscillation shown in figure 18 corresponds to the period of the analyser in the corresponding section $d x$, and the amplitude of the oscillation shown in the extinction curve is determined by the amplitude of the oscillation of the corresponding frequency in the saw record
 210 By making a negative/which will be called the second intermediaty film) from the film 205 we obtain an extinction curve for the given section $d x$ of the negative which is shown in figure 19. Figure 19.corresponds to the extinction curve of the film 205 shown in figure 18. In making the negative the two films 210 and 205 are held apart at a certain distance and the light used for the copying is not strictly parallel, but diverges within a plane which is perpendicular to the film and

## Page 15.

parallel to the $y$ axis. The divergency should be greater for sections $d x$ which correspond to lower tones. If one copies in this way, the negative 210 will not show the oscillations of figure 18 but only the mean values of the extinction. This is indicated in figure 19.

If film 205 and its "blurred" negative
X. 210 are placed one on top of the other and copied on a third film 211 (which will be called the third intermediary film) onecan get, by using a developer containing bichronate
potassium or other suitable processes for developing, a hard copy. Figure 20 shows such a copy which corresponds to the extinction curves shown in figures 78 and 19.

Figure 21 shows how to transcribe the third intermediary film 211 into the modulator film 212 which we need for our system of reproduction. 82 is a light source placed in the focus of a lense 221 which makes its light parallel and throws it across the slit 222 and the third intermediory film 211Xeserass


 810

 on the film 212 While the film 211 is moving quickly 212 the film 2fig mowes slowly and on a single section $d y$ of the film in front of the slit 222 a large number ( of individual humps (shown in figure 10 ) of the film 211 will be impressed.

Instead of using a sound generator film as hitherto described one can also use a sound generator disc

Page 16.
as shown in figure 22.
In figure 22.230 is the sound generator
disc (a glas's disc on which the oscillations are photographed). 231 is a slit the width of which can be varied (and thereby the basic time of reproduction). It is practical to use a smaller basic time for a quick têmpi for instance allegro and a larger basic time for andante. 232 is the modulator film.

In reproducing sound by the arrangement shown in figure $I$ one must take care that the width $\Delta y$ of the slit 4 should be small enough in relation to the smallest wave length $1 / \mu$ photographed on the sound generator film 3. If one wishes to use a wider slit $\Delta y$ one could increase $1 / \mu$ but this is not very convenient for the following reason: if we increase/we have to increase the velocity v at which we move the sound generator film in order to generate sound of the same frequency/as before ( $\nu=v \mu$ ). It is therefore better to use an arrangement shown in figure 23 which enables us to use a larger $\Delta y$ for the same soundgenerator film. In figure 23 we have a light source 240 , the light of which is made parallel by the lense 241 and thrown on the slit 243 , the width dy of which may be larger than the smallest wave length $1 / \mu$ on the sound generator film if we use the arrangement as described in the following: in front of the slit is moving the sound generator film 242 as described in figure 1 , but there is another strip of film 244 fixed in front of the slit which is exactly alike the sound generator film 242 only at rest in front of the window. (Each individual section $\Delta x$ hars the same $\mu$ on both films 242 and 244.)

Page 17.

The light transmitted by the slit 243 traverses the modulator film 245 and enters the photocell 246. The current generated by the photocell controls the loud speaker as described in figure 7.

The method\& for manufacturing the modulator film which has been described in figure $15 a$ and $15 b$ make it necessary to have first an ordinary sound record on a film and to transcribe it afterwards into a record (the modulator film) as required by our system of sound reproduction. We shall describe in the following a direct way of arriving at our modulator film which has the great advantage that we save the ordinary sound film (which is very long as compared to the modulator film).

In figure 24250 is a cathode tube, the intensity of the cathode rays emerging out of the window 251 of the cathode tube being controlled by means of the grid 252 by a microphone (the speech or music acting directly on the microphoned. The cathode rays, the intensity of which is following the oscillations of the sound, strike a rotating disc 254 at its cylindrical circumferance 255 which is coated by a luminescent phosphor. This phosphor is so chosen as to have a sufficiently low extinction coefficient; if the velocity of the periphery of the disc is of the order of 1 metre per second the light emitted by the phosphor in front of the lens 256 should still be strong enough to permit photographic recording in the process described below. The lens 256 projects the image of the section 257 of the periphery $25 \%$ of the disc 254 on the slit 258. An analysen built in the same way as sound generator films are built, is kept rapidly

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moving in front of slit 258 in such a way that many
 analyser 259 enter the slit 258 while the disc 245 moves only by a fraction of the corresonding wave. (the velocity of 259 is large as compared to the velocity of 255). On the surface 255 the luminosity is constant as a function of the $x$ coordinate and a function of the $y$ coordinate which the shows the oscillations of the sound. The section 257 takes in every respect the roll of the film 161 in figure 15. A mirror 260 in front of the slit 258 projects the image of the slit on a photocell 261. The mirror is quickly oscillating round the axis 262 projecting thereby wus one section $d x$ after another on the photocell 261. The oscillations of the mirror 260 are slow in comparison with the oscillations of light generated by the motion of the analyser, but the oscillations of the mirror 260 are quick in comparison to the motion of the disc 254. The photocell 261 controls a cathode tube 263 in the same way as described in figure 15. The luminous spot of the cathode tube 263 is projected by the mirror 264 on the film 265. The mirror 264 is oscillating round the axis 266 synchronised with
ta/mirror 260 so that when mirror 260 is projecting the image of a definite fefftrox section $x$ on photocell 261, mirror 264 should project/the lumin 261, mirror 264 should project/the Iuminous spot of tủbe 263 on the corresponding section $x$ of film 265.






















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$\frac{\text { undated }}{\text { Reprod. of Sound }}$

The Invention concorms a mothod for
poglatering sound, for Instance sponeh ox musie by photogrephic methods on a strip of filng and reproductug It for inatance by sonitng 11 ght thurough the f 13 m and uatng a photocell to acnvert tho verviettions of 12 cht 3nto sound.

Figure 1 in2ustratea the prinotgle of the
 meglatored by a new nothod which wi23 be oesozibod furthos
 11eht almitted to the photoonil 6 has to possa not oniy sist 4 and thet section of the rixa $y$ which is in front of allt 4, but also a quilckiy moving plan 3 in the bonaid genervtor which is contimousig revolting in steele pasaing in front of silt 4. in opticnl lense 2 mnkes the 21 ght of the 12ght soruse 3. pera3lel and throwa 36 eaross the sound genomator riln I the si2t 4 the the roolulatos 822 m on tho photocel2 6 . thorona the sound genomator f 2 zm is nivegs the sene for overy plece of musie of apeech the motulator faln s cemples a Fecose of the individual piece of apoech op arasie which 2a to be vopyrolnced.

In Pigure 2 zou see two pleces of the rizn atrlps whth move peat onch othor drewn below one another.
 soettion $y$ whtah is in front of the alit 4 corwosponis to a pertod of tino of $3 / 20$ to $3 / 30$ of a socom, thet Is to ang thet in $1 / 20$ to $2 / 30$ of of a soeone the

Bace 2.
soction $y$ passes the slit 4, and after that tine a now section of the modulator film w112 be in front of the silt 4. This period of tine (which may be $3 / 200 \mathrm{~h}$ to $2 / 30 t h$ of a secona) wili be called the time basis of the record. If one goes within the section $\mathcal{F}$ Erom Lert to plght across the flim 5 ono pesses 12 sections and tho tronaposency of esch section (the anount of light ench section ( 1313 allow to pess) cetemnins the composition of the sound whtch is produced at the monent whon the section $y$ is in front of the slit is We heve draw 12 sectlons in order to simplify the arewing, but In roality the nubber of soctions will at least be 200 or any mumber beyond that. If the mumber of sections $x$ Ls very large one gots a contanuous ourve by plotting the transpasoney of the fila 5 as a funotion of 5 for a derintte section $y$. Such a curve is shown in PIguso 3. It gives the frequency apectrum of the sound at a cerinlte moment within the basic period of time. $X$ need not be a atrect moasure of the frequeney, but the froguency is a function of $x()$ the form of which can be chosen to sutt certain reguirements. The rim 3 In Pigure 2 is also envided into 12 seetions $x$ $(x, x, x, \ldots \pi)$, Withtn each of these sections $z$ the tronsparoncy veries along the film as a simus Iunction of $\bar{y}$ (transparenoy $=$ ). is a constint i.e. Ats value does not vaxy with $y$ but $1 t$ vardes from one section $x$ to mother belng a function of $z_{\text {. }}$ of course vaples also from one section $z$ to enother being a function of $\pi$ If the palm 5 would romain stred tho soction
boing in front of the a12t 4 and tho filn 3 voula be moved past the glit 4 vith a voleelty $\%$ one would heas a mound ocuyosed of 21 Freguoneles 1.0. the froguoneles oseh of thou whith an

Intensity abtorvalned by the transparonoy of film 5 at the comesponaling seetions

- The
tnatviduna, values of the tranapuroncy for the dorintte ceat2ons $z$ oas be soen from tho cuxvo in figuro 5. If r12n 5 mocke not nove vo would elvags heas one ask the same sound compoaed of the anld frogueneles with conatant intonsitiles. Howevos the fins is moving alowly so thet after $3 / 20$ to $3 / 30 t h$ of a second another section $\bar{y}$ is $4 n$ front of the silt 4 and wo ahail therefore hens a vexying sound which is conposed of tho
 acyine an intensity wieh is controlice by the transparency of the alfroment acettong of fila B. if wo have a large numborod freguenelos (a lewge nunber of sections

3) we can get a vary good reprocuction of apeech or matco.
pigure 4 ghow an oxtuple for wecording
intonaletes on the modnkntor filn 5. Eech section $\pi$ has a bronspesont section shrwounded by two non-transparent acetions. The anount of 24 ght trensuttted by soction z Is thus proportionate to the vidth of the trenspspent section which varies slong the esing, the vidth being a efmetion of $z^{*}$

Whguse $\$$ shows enother asmple for secordins intonsitiea on a moduletos rakn 5. these wo heve within eseh section $x$ a "Erunsperent" section between two
pace As
nons "trensparent" sections. the breadth of the "transparont" section is constant along the p1am (it butak does not wary with y), wut the "transparent $t^{\text {b }}$ acetion is not completely bransperent, its extinction varies along the fllu ( 3 a a Eunction of y ). Both ways of recoraing usod in figures 4 and 5 can be combinoc, is necessary, leading to a "transparent" soction, the brosath and extinction of whith vertes along the riza.

I8 the sidt 6 has a wiath of $1 / 20 \mathrm{~mm}$, and the basie period of time of the reproduction is $1 / 80$ of a second the moduletor $\mathrm{ri2m}$ noves 2 m pop second 1.0 . for the reproduction of a pleoe of maste, the perfomence of which lests one hour, one wil2 need e si3m atsip of the length of 7.2 metres. The sane will hola if the silt 4 has a viduth of . 05 man and the basio period of poproduction is $1 / 40$ of a second. It is not necessery to use a sist 4, the with of whith is constant aeross the Pran.

As shown in figure 6 the width of the slit 4 may very with $x$, the slit being naprow at the right ond where the high frequenczes ape controlled, and belng wider at the lert ond whope the lover frequencles ave controlled. It has an advantage to use such a slit whith makes the Baste portod of time smaller for the htghor frequencios then for the 10 wow froquenctes.

The sound genorator piln 3 whil in nost casos be moen with verying extinotion along the riza and used in conbination with a moluletor riln of the type ahown in Prause 4. It is, howevor, possible to reverse the
2089. 5
conblnation and use a modulator raln of the typo shown In figure 5 , ana a sound genoratos film shewe the transppareney of osels section $\Delta x$ is cronted by a trensyurent section withtn eech scotion $x$, the wicth of the anid transperent section vaxying ulth $Z$. Ef courge a sound senerator sila of the s1rat mentionod ty: een be used also sm acmbination with a modulatos film of the typo ahon in escruve su]

It hes been montsoned that the number of the sections as wil2 bo kerge and on be anything above 200 , for instance is the lowest freqquency which we wish to Incivele in tho reproduetion is 200 , and the highost froqueney is 3,000 , and if wo wish thet the eifresence betroen two ndjacont freguoneses should be nbout $\Delta \nu=\frac{\nu}{100}$; i.e.
$1 \%$ of the frequency we shall have to uee sbout $N=\frac{5000}{100} \times 2$ proquencies, where $z$ is given by $e^{z}-\frac{5000}{100}$; i.e. $A \approx 200$; $N \cong 400$

W2guse 7 ahows the usun exrengenont of transforntng the variablong in the Inteasity of the 2iche (that enters the photoce21) into sound. C is a photoce11, 72 its cathode whidh is comeeted through a high realatence 78 so polnt 73. Polnt 73 Is comnectod through a eosconsos 74 to point 75 ant point 75 is commectod throych a ansil mosistanco 76 to tho anode 77 of tho hotoce13. 6. Point 75 is conmected through a prosistance 70 to tho poeltive pole 70 or a hrgh voltage bnttery 30 . The negetive pole 81 of this high voltaco battery 13 connoctod through a mmi bettery 32 to point 73 and to the glowing ramonont 83 of a valve 35. The grid 34 of this valve is o onncoted to the cathode 73 of the photocs 12. The anoce 36 of the vnive 35 Is
comocted to one ond of the primary 97 of a tranaformer 98 the other ond of the prilunyy being comeeted to point 99. Potnt 39 za oonneeted through a rosistanco 00 to the 79 yonttive pole 2 /of the high voltage buttory 90 on the one hund and thyough a condensor 01 to the nogetive pole 01 of the same high voltege bettory on the othes hand. The secondexy 98 of the transforner 38 is connaoted to en anpltryoz aet 03 whteh feods tho loud aposicos 94.

Phgure shous enothor esrengonont whioh sozves the anne purpose as fitguve 1 , nomely the purgose of peprodueing the sound aecostad on flin 3. 101 Is a light sousee placod in the focx of the opticel lense 202 viluh thurows pervallel 11 ght acyons the slit 204 and the sound genoraton 205. A aecond optical lanse 207 projeots the tranco of the gound gonernting isku 103
 305 felle on the photocol2 100 . A transpersent gless plate 209 aiverts aomo $\mathbf{3 i g h t}$ by rorlection at sta of the 133 m 103 in front of 100
 309 on the photoce21 220, The une of the aecond photogell 130 哣 the rolloulng

IS, fos the wecowding of sound on the moarlator sum 5, the mothod indionted in cigure 5 is used it is somettres afreicult to seach a vory hteh extinetion 1.0. the trenspespeney of the socttons $\quad 2$ hes, though a vory sma3. 耳ot EnAtte value evsa in the absonce of the Iroguenolos.tn the sound which ought to be rocosded. If the sooond photocelı were not prosont weale 11ght of $\mathrm{al2}$ srequeneles woula reech photocoll 100 in all eircuratences end would produce diaturbing aounde. it one uses a
second photocell 110 which gets light atrect from the sound generator film the filter 209 an be so adapted that the ourrent generebed by 210 should for every frequency compensate the curpent generated by 106 for the same frequency in case the tronsparoney of the compesponding section $x$ of the sound modulating filn 205 has its mintmun value (which signifies the absence of the corpesponding sound that hes to be recoried).

Figure 9 shows how the photocells 100 and 120 are used. $\quad 125$ is a high voltage bettery, the positive pole 116 of which sa comected to the anodes 217 of the cell 110 and the anode 118 of the oell 106. The cathodel19 of the cell 106 is connected to point 120 and the enthode 121 of cell 210 is comnected to point 182. the negative pole 123 of the high voltege bettery is connected to point 124 whtch is comected to the positive 132
pole 125 of a small battory, the negative pole 126 of which is comnected to point 127. Point 127 is connected through a high resistance 128 to point 120 (mhtch is connected to the oathode 119 of the cell 206), and point 127 is also connected thpough another high sesistance 129 to point 122 (which is comected to the cethode 121 of the cell 210). Point 127 is conneeted through the condensor 130 to point 151 to which the positive pole 128 of the small battery 132 is also connected (through polnt 124). Point 130 Ls comnected to the cathodes 133 of the valve 134 and 135 of the valve 136 . The grid 137 of the valve $\mathbf{2 3}$ is comnected to point 120 and the grid 138 of the valve 136 is connected to point 222. The anode 139 of the valve 134 is connected to the end
of the pathary col3 142 of the trenofomaos 342. The snote 143 of the velve 136 Is connoeted to the other ena 144 of the prinury coll 242 . The ratdale 145 of the prixnsy cell 344 In connocted to the positive pole 336 of the migh voltege battory 135 . The secondary 346 cen De corunctod to an enplifyez aet and a loud speaker ss Coscribed previouniy in sigure 7.

If the recoraing of the aound on the nodulator filu 5 in popiomod in a manoy indicetod in figure 5 one noed not have a 3 intted mubes of seettons s with exe saolntod from onch other by blecironod stritps 52, 52,53 *** *. within seoh seetion $y$ the transpuroney of the film oun be perfeetiy contimuous function of zo $\quad$ Tt had edyuntages to vee such a
 gonerator $\mathrm{Sa2}$. Wo on got "mooth ${ }^{6}$ sound gosarator ctuna in durforent wegas

Figuve 30 givoa an indicution of an "amooth"
acum anomator faln A atmus function of a cestain wave zength is photogmphod on section 3 of the f 11 m (1.0. the trenspervoncy varsoa vith y along section 2 aceoraly to If enother almus function of a alightly diefosent weve longth is photographad on section 2 soetion 3 and soetion 2 awe ovor-legping as indicatod in flguse 20. In tho sume vey e thind alnua function is photograplioe on soetion 3 , the vave longth being again shartea a 3 attlo egninat tho wave longth of seetion 2 . geettion 3 is over-lapping seetions 2 and 2 in the mennor Indsentod in sigure 10. If 11 ght is adndttod by the


## Raco...

definite apot ar of tho sound genosntor sklu a sound v111 be procuood mich v111 comteln a navrow bend of rrequencies, the contre of gravity of whteh vill be Cetcratmod by $\frac{\mathrm{y}}{\mathrm{D}}$. The broedth of the bend depente on the breeath/of the sections $2,3,3, \ldots$, on the shife a of those seettons with zeopect to oneh othos, the on the shast of froquaney fron shen scetion to anothas. The breadth of the bnen prodseed by 21 ght tronsatited at a derintte spot 26 win mpprostmately be

If we wial to sopwoduce musie it is Anpowtunt


). is thas conaltion is furergiod (
) a man 12 ahufe of tho mocuatov film with pospect to the gound genorntog rala in the atrootton yt of tho on nala will not alstont the masie but only change the keys for znatanco a falkiy lerge anist would lond to the sme maste botnc played hals a tone htchor or 2 ower. (Tt may be statod that our systom of sound seprodisedny malrea it poas2ble to wery the terps Dy varying the apeod of the modulatov fatm mithout changtny the speod of the sound generetos stza).

## Figuxe 22 strass Inctantes a speeicl type

 ond 158 which are crum paraliel to the x atta acsoss the gizm dotine a section $\bar{y}$ of the filn wheh corresponas to a cortaln longth of timo say $2 / 20$ to $3 / 40 t h$ of a secona which we wil3 anil the busic longth of tine of the acund gonesptos filn of this bype. The 11 no 253

Indicates the malale of the section $\bar{F}$. The trensparoncy of the 812 m in tho section 1 ia given by the 3 co-osdinate of a function $\quad \sqrt{5}$ being/the milate of seetton $\gamma$,
E. Thia furiction sa show in figure $21 a$. The tranapuroney of the film in the section 2 (which is shiftod in roapect of section 2 by $a_{s}$ and is over lapping section 1) is given by a function
boing mitetme alightly alfrevent from . This function te ahown tin figure 12b. The seme applles to section 3 and so on.

The next acetion $\bar{z}$ betweon 188 and 184 is mede oxactly aztwo the section/botween 151 and 152 ; sgain ali the sumotions copled within this aection y hove thetr mextima in the midale of the section 255. The sam holde for the overy following aeotion $\bar{y}$. The boundartes of the soctions $y$ need not be parallel to the $x$ oxis, but can have a slight alope as inatcated in fuguse 12.

One can elao heve a basie Jength of timo of the sound genosutor fila which 18 a function of $z$ the the boing largos for the lower tones then for the highes ones. This is inaicnted in etgure 23. Figure 24 shows nother mothod of registoring aound on the moduletor P 1 l . 5 . The Erensparency of the Plam voplos continuously (es a conthuuous function of $z$ ) across the exlus. That is brought about by having nonCransparent and fransparent lines runnlng at $45^{\circ}$ to the z arts across the $\mathrm{f} 1 \mathrm{3n}$, the brendth of the transpasent 2 nnea boing a funotion of z.

Hethods wil be described whith make it

Page 12.
possible to manufacture one of the above mentioned types of sound records on the modulator film. We shall assume that we have an ordinary record of a plece of music or of apeech on an ordinery film, the sound being registered in one of the two usual types of registering 1.e. . We shall describe mothods for transcribing this usual type of record Into a sound record on the modulator film of one of the types mentioned above.

In Pigure 15a 160 is a film similar to the sound generator films as described above. 161 is the a plece of music of speech film on which/thes ssound is recorded in one of the two usual ways. The light emerging from the light source 162 pleced in the focus of the optical lense 163 is made parallel by the lense and thrown through a section I of the shond generator film 160 and of the film 161. The length $\Psi$ corresponds on the record 161 to a certain longth of length of time the basic/time of the operation of transcription ( ). While a certainsection of the record 161 is in front of the window 164, the film record 161 being at rest, the 511 m 160 which will be called the "analyser" is kept moving. The light transmitted by the $s$ ection $X$ of both films is collected by the lense 165 and thrown on the photocell 166.as As shown in ifgure 15 b the window 164 admits only 11 ght across a small section $d x$ of the analyser. By shifting the analyser in the direction of the $x$ axis aifferent sections $x$ can be brought in front of the window 164. For a given soction/of the analyser representing a given mean frequeney in front of the window and maxtury rixim stra surastigex kept moving in the direction of the $y$ axis while the $141 m$ record 161 is at rest the 11 ht

## Pege 32.

tranamitted by the fivo fllua will have a varying intensity. The amplituce of the veriation will bo detemined by the intonsity of the oaciliation having the froquency on the 121 m recosd 161. Therefore the mplitude of the altormating curyont gonerated by the photocell 160 vil2 be deternined by the intensity of the oselilation on altormeting
on the filu rocom 161 . If the/oument generatod by the photoce11 266 is ampliried and used to control the intonalky of a 21 ght souree $20 \%$ the 11 ght of which is thrown through a slit 163 on a section dx of the siln 169 the transpurency of the section ax vill be deteruined by the intensity of the osciliation on the Pilm recoxd 261. $\quad$ y shasting the film 109 together with the analyser 160 paralle1 to the $x$ exts, different spote $x$ of the analyser are brought in front of the slit and at the samo time 164 tegethem watt/atfromont spots $x$ of the 821 m 260 ase brought in front of the sait 263. At oach eetion ix at the spot z of the flis 209 the intensity of the corresponding oscillation on the rilm record 161 ta zughtadnask gets thus registeroc. 169 or negatives of 2t oan be used ns moduletor falm for our nothod of sound reproduetion. The operation of transcription consists of the repetition of two alternative operations: the analyser 160 and tho rocord 169 are togother ahsifted forvards and bachwards along the $\pi$ axis while the analyser is revolving fast and the film rocowd 202 Is at a stand stil2 as wel2 as the record 169. Shasm as acuraxt sksy During this motion the 117 m 1.61 is exposed to the 1ight of the 21 ght source 167 . The motion being completed the 512 m rocond 161 and the fl 1 m 169 ame noved along the $y$ exis by a length copresponding to a fraction for

## Page 13.

Instance $1 / 20$ of the basic length of time of the transcription operation (for instance 161 is athifted moved along by $1 / 10$ of $Y$ ). Then 161 and 169 are again shifted forwards and backowards perallel to the $x$ axis while the 11 ght source 167 acts on the 111 m 169 and so on.

The current generated by the photocell 106 is amplified in the same menner as shown in figure 7 , the only difference being that the loud speaker in rigure 7 is replacod by a suitable light soupee for Instance a cathode tube with Iurinoscent screen. In Pigure 16175 is a Brown tube. The electrons omitted by the ellament 176 are controlled by the cylinder 177 which is connected through the negative pole 178 of a small battery 179, the positive pole 180 of wich is connected to the socondary 182 of a transformor 182. The other pole of the secondary 181 is comected to the cathode 176, the prinary/of the trensformer boing connected to the anplifyer shown in figure 7. The two ends of the pllamont 176 are connected to the poles 184 and 235 of the hoating battery 186, and the pole 135 is connected to the pole 187 of the high voltage battery 138. The positive pole 189 of the said high voltage battery $1 . s$ connected to the anode 190 of the tube 175. 191 is a luntnescent screen enitting light under the influence of the cathode rays, the intensity of the light being controlled by the amplituce of the alternating current generated by the photocell. The tube 175 acts as rectifyer in the same way as an audion. The battery 179 is maintaining wakesstan such a voltage at the "grid" 177 that one half cycle shoula get surpressed.

In the following another method of transeription

## Paco 14.

vilit be doseribed which only maleos use of photogrephic mothods. In 21 gure 17200 is a lifat souree placed In the foeus of a lenso 201 projecting perallel Iteht on the analyser 208 and on tho aection $Y$ of the $f 1$ In 203 on which the ptece of mustic or speech is recorded in one of the two wesual zays of recoselng. A cylindrical Lense 204 concontrates the light transmitted by 208 and 203 on a small aection ay of a riln 205 whtch will be callod the first intermodiary riln. The ilght of esch section ax of the f 12 m 203 w121 bo concontrated on the eompeaponaing section ix of the first intorvodiary 811m. The 412 ms 203 and 205 ape aimultanoously moved through the apparatus, both fiks moving for instance at the sme speod. A givon section ax of tho film 205 will show after betng aeveloped an extinction ns Indiceted in figure 20. The pertod of oselilation ghown in figure 10 comresponds to tho pertod of the analyser in the compesponding sectiton Ax, and the axplifute of the oscinaation ahown in the extinction curve is dotervinod by tho mplitude of the onctilation of the cozvesponaling froquoney in the swuwat rocord
 By making a negativo/thich will be called the socond Intermoataty 5 I2m) from the $\sin 205$ we obtain an extinction ourve for a given section dx of tho negative whioh is show in Pigure 19. Figuro 10 compesponds to the extinction curve of the $832 \pi 805$ shown in figure 28. In radcing the nogative tho two 231as 210 and 205 sare hold apart at a cortain dsatance and the light used for the oopying is not atrictiy parailel, but diverges within a plane which 28 perpendicular to the 121 m end

## Page 15.

parallel to the $y$ axis. The divergency should be greater for sections dx which correspond to lower tones. If one copies in this way, the negative 210 will not show the oscillations of efigure 18 but only the mean values of the extinction. This is indicated in figure 19. If film 205 and its "blurred" negetive 210 are placed one on top of the other and copied on a thisd film 211 (which will be called the third intermediary film) onecan get, by using a developer containing potassium bromide or other suitable processes for developing, a hard copy, Figure 20 shows such a copy which corresponds to the extinction curves shown in figures 18 and 19.

Figure 21 showa how to transcribe the third intermediary film 211 into the modulator film 205 which we need for our system of reproduction. 220 is a light source placed in the focus of a lense 221 which makes its light parallel and throws it across the slit 222 and the third intermediary film $211 /$ rexsess
 sाим


 on the film 205. While the film 211 is moving quickly the film 205 moves slowly and on a single section dy of the film 205 in front of the slit 222 a large number of individual humps (shown in figure 19) of the film 211 w111 be impressed.

Instead of using a sound generator gilm as hitherto described one can also use a sound generator disc
as shown in sisuro 22.
In rigure 22 2so is tho sound genowator alse (a glas disc on whath the oscillations are photographed). 231 is a slit the width of which can be variod and thereby the beste time of roproduction. It is practieal to uso a maller basie thmo for a guielc tamp for inatance allogro and a larger basie time for andento. 232 is the modulatos 813 wn

In rogroduetry sound by the arrangonent show in eigure 1 one muat take ceme that the width $\triangle y$ of the slit 4 should be suall enough in rolation to the smajlest vevo Longth $1 / 4$ photographed on the sound gonerator filat 3. TE one vithes to use a wider sitt $\triangle \mathrm{y}$ ono could inesense $\mathrm{z} / \mathrm{c}$. but thia is not vory convontent for the following reeson if wo inerease/ve have to incroese the voloolty v at which we move the sound generator film In order to genergte sound of the swe frequoncy/as berowe $(\nu=v \mu)$. It is therefore botter to use an arrangonont show in 1 igure 25 with onables us to use a lexges $\Delta y$ for the sane soundgonergtor filn. In Ingumo 23 we havo a 11 ght souree 280 , the 14 ght of which is mado parailel by the lonse 243 and thrown on tho slit 243 , the width dy of whieh mey be Lugros than the anallest wnve zength $3 / \mu$ on the sound gonerator cilun is we use the arrangenont ns describod in the followings in front of the slit is moving the sound gonowator siln 242 as deseribod in figure 1 , but there is anothor strip of filim 244 fixod in front of the salit whith is exactly aldice the sound goneratos $£ 13 m 842$ only at rest in front of the windov. (Each individual section $q x$ have the aane $\mu$ on both $f 11 \mathrm{~ns} 248$ and 244.

The 12ght transmitted by the alit 243 trevorses the modulator film 845 and enters the photoce11 846. The cussent gonereted by the photoceli eontrols the loud speaker as coscribod In Pigure $\eta_{0}$

The mothod fos manatecturing tho modulator fikm which has been described in pigure 25 and $15 b$ malte it necossary to havo first an ordinary sound pocord on a pilm end to franacsibo it srtorverds into a secord (the modulator fizm ) as requatred by oup syster of sound roproduotion. We shall closeribe in the following a diroct veg of aryiving at ous modulator giln whteh hes the gront advantago thet we save the ordnury sounc film (whtch ta very Long as conpared to the modulator fala).
in exguve 84850 is a cethode tibe, the Intensity of the cethode sags emerging out of the window 201 of the cethoce fube being controlled by moens of the grid 258 by a mlerophono (the sveech or masic acting atroctiy on the aterophoned. The cathode reys, the antensity of ehrich is following the osetiletions of the sound, stritce a potebing atse 254 at tio cylinditon otrounferance 255 which ta coeted by a Iuminescent phosphon This phosphor is ao chosen as to have a sufriciently low extinotion coerricients if the veloelty of the poriphery of the asse is of the ortor of 1 motre pes second the 13ght omitted by the phosphor in spont of the lens 256 should sti2i be atrong enough to permit hotogrephte pecording in the process cesortbed bolov. The lens 256 projects the innge of the section 257 of the pertphery of the dise 250 on the allt 250. An anazsor, brilit in the

zeco. 23.
moving in srome of alit 253 in anch a way that mexy
 alaigeos s59 onten the sait 850 thaze tho asse 245 movos only by a freotton of the corres onalng weve. (the veloctive of 259 in lexge as compered to the veloctty of 255 ). On the surfece 255 the 3 wninosity 1 a constrent es a function of the 3 eoortineto end a funotion of the $y$ coordinete which the whow the oseiliations of the sound. The meetion $25 y$ taltes in everg respoct the goll of the rinn 261 in figuse 15. A mireos 200 In front of the allt 250 projects the smage of the salt on a photocel2 202. The utrwos is eqtelay osctilating pound the exta 200 projecting thovoby zae ono soction dx efter another on the photocell 203. The osez12ntions of the atrwos 860 aro slow in compasison with tho osciliations of aight conoseted by the motion of the annlyses, but
 to the motion of the aleo 254. The photocell 202 controla a cathoce tubo aps in the suse why as cosoribed In rigure 35. The Iualnous apot of the cethode sube 203 2a projected by tho miryor 804 on the r12m 205.
 with
te/mivery 360 so thet whon ntmos seo ta projoeting the imace of a ceflnito faratitun section $z$ on photocell the imege of 802, mitros sed should project/tho 2untrous spot of tibo sas on tho correaponding aection $z$ of 8123 aac.

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## E0171 3.

RROVASTONA, SPMCIETCAETON,

I, Lwo SzThand, of Ceman nationality, of 8, Keeble Road, Oxford, Oxtordshire, do hereby declare the nature of this invention to be as follovis -

The invention concerns a mothod for rogistering sound, for instance spoeeh or music by photographic mothods for instance on a strip of film , and reproducing it for instance by sonding light through tho film ane using a photocell to convort the vartations of light into sound.

Hitherto in sound recordinc, a rocord has usually boen made of the actual wave rom of the sound to be recorded, either on a film by the woll known variablo widtic or veriable density methods, or on e eramophono or similar record. The dieadvantage of such records Lies in the fact that, in order to rocord itoms lasting for any longth of time, a large anount of recording gaterial (be it 441 m or wox or 11ko matorial) has to be used, due to the ract that, in reproduction, tho record mest pass at a considorable speed throuch tho roproducing davieo.

It is an object of the present invention to provide a method of and moens for recording and reproducing sound wherein this dirfioulty is overcome.

According to the presont invontion there is providod a method of rocording and roproducing sound whoroin a rocord is made of the changes in amplitude of each frequency (or mall band of freguencies) over the whole rance of sound to be recordod. These records may be disposed alde by side upon a fl am,

Furthor secording to the present invention there is provided apparatus for producing such records, and for raproducing sound therafrom.

The 1 nvention wil2 be 112ustrated by way of example with reference to the accompanying drawinge in which

Fies. Ia and 2b inluetrate the prinoiple of the invention,

Figs, $2 a_{2}, 2 b_{2} 4$ and 5 illustrate types of records produced eccording to the presont invention,

Pig. 5 is an explanatory diagrom,
Fies. 6, 7, 9 and 9 aro forms of apparatus or parts thoreos, for earrying the invention into affect,

Tige, $10,11,21 \mathrm{a}, 11 \mathrm{~b}, 12,15$ and 14 show further typos of records produoed according to the present invention,

Fige. $15 \mathrm{a}, 15 \mathrm{~b}, 16,27 \mathrm{a}$ and 27 b show further foxms of apparatue or parts thereor,

Tige. 18, 19, 10a and 20 are explanatory diagrams,
Fies, $21,28 \mathrm{a}, 22 \mathrm{~b}, 23 \mathrm{a}, 23 \mathrm{~b}, 24 \mathrm{a}$ and 24 b are further foxms of epperatus according to the prosent invention.

Reforring to rig. 1,5 is a film oallod horoinafter the modulator siln on which speoch or music is registored by a new mothod which will be furthor described below. This riln moves slowly past the slit 4, and the light admitted to the photocoll 6 has to gass not only slit 4 and thet section $\Delta \mathrm{y}$ of the film 5
which is in front of slit 4, but also a quickly moving endless film 3 which will be callod the sound generator. An optioal lons 2 renders the $1 i$ ght of the 11 ght source 1 parallel and throws tt across the sound genorator f1lm 3, the sll.t 4 and the modulator isim 5 on the photocell 6. Whereas the sound gonerator Pilm 3 is always the same for overy plece of musio or speeoh, the modulator Pilm 5 carrios a rocord of the individual piece of speech or music which is to be roproduced.

In Fig. 2a is shown a strip of the film 5. A section $\Delta y$ which is in front of the slit 4 at any instant passes the slit 4 in a period of time which may be 1/10th to $1 / 40$ th of a socond, and which will be called the time besis of reproduction. As shown in Fig. $2 a$, the section $\Delta y$ is made up of 11 seotions of width across the film $\Delta \mathrm{Z}$. The transparonoy of oach section (i.e. the amount of light each section will allow to pass) determines the composition of the sound which is produced by the film 5 at the tine when the section $\Delta y$ is in front of the slit 4. Only 11 sections have been shown in order to simplify the drawing, but in practice the number of sections wil1 be at least 200. If the number of sections $\Delta I$ is very large, a continuous ourve may be obtained by plotting the transparency of the film 5 as a function of $x$ for a definite section $\Delta y$. (In this description $y$ refors to distances longitudinal of the Iflm and x refers to distances transverse of the film.) Such a curve is shown in Fig. 3. It gives
the frequency speotrum of the sound at a dofinito momont Within the time basis of reproduction. z nood not be a direot massure of the frequency, but the frequoncy is a function of $\mathrm{X}(\boldsymbol{r}=\boldsymbol{f}(\mathrm{x}))$ the form of which can be chosen to suit requirements. The film 3 is shown in F1g. 2b, and is also divided into 31 seotions $\Delta \underline{x}$, the seotions boing mariced $x_{1}, x_{8}, x_{3}-\cdots+\cdots-x_{11}$. Within each of these seotions $\mathbf{A X}_{\mathrm{X}}$ the tronsparency varies along the 51 m as a sinus function of $y$ (transparency $=$ $A(x) \sin 2 \pi \mu(x) y)$. A is a constant for any one section $\Delta x$, and varies from one section to snother. $\mu$ also varies from one section to another, and is a function of x .

If the 213 m .5 were to remain ifixed, a given section $\Delta y$ being in front of the alit 4 , and if the film 3 moved past the slit $\&$ with a veloot ty $\bar{y}$ one would hear a sound composed or the 11 frequeneles recorded on the film 3, 1.0. the frequencies $\nabla_{\mu} x_{1}, v_{\mu} x_{2}-\cdots-\cdots x_{11}$, each of them with an intensity determined by the transparency of rilm 5 at the corromponaing sections $x_{1}, x_{2}, x_{3}-$ $x_{11}$. The individual velues of the transparency for the correaponding sections $\Delta x$ oan be seon from the curve in Figure 3. If film 5 did not move we would always hear one and the seme sound composed of the said frequencies with constant intenatties. However, the film 5 moves sloviy the thet after $1 / 20$ to $1 / 40$ th of a second another soction $\Delta y$ is.in front of the slit 4 and we shall therefore hear a varying sound which is composed of the
froquoneios which aro genorated by film 3 , oach Sroquoncy havine an intonsity which is controllod by the trensparency of the different soctions of tilm 5 . If wa have a Large number of froquencios (a laxge numbor of sections $\Delta \mathrm{x}$ ) we con get a very good roproduotion of spooch or มuรic.

IIgure 4 show the namer in which the intonaltios are rocortod on the modulator film 5 . Fach soction $\Delta x$ has a transparont noction surrounded by two non-transparent seotions, The anount of 31 ght tranmittod by soction $\Delta_{\mathrm{x}}$ in thus proportionate to the vilth of the tranaparont soction which varies alome the siln, tho wiath boine a funntion of $z$

Ficure 5 shows anothor mannor of rocording intonaities on a modulator Pi . 5 . Hore wo have within oach moction $\Delta x$ a "transparent" seotion between two non-"trangpasont" seettions 52, 52 otc. The breadth of the "transparont" soction is constant along the film (1t does not very with $\mathcal{Z}$ ) but the "transparent" gection is not complotely trunsparent, its dansity varies along the film (ile a function of $z$ ).

Both waye of recording used in piguros 4 and 5 may bo combinod, ir nocossary, leading to a "transporent" scetion, the broadth and extinction of which varios along the piln.

If the elit 4 has a vidth of $2 / 20 \mathrm{~mm}$ and the basie poriod of time of the reproduction is $1 / 20$ of
a second the modulator film moves 2 mm . por second, 1.0 . for the reproduction of a pieee of music, the performance of which lasts one hour, one will require a film strip of the longth of $7 \cdot 2$ motres, The same will hold if the glit 4 has a width of .05 mm . and the basic period of reproduction $1 s 1 / 40$ of a second. The width of the slit 4 need not be constant across the film.

As shown in Figure 6 the width of the slit 4 may vary with X, the slit beine narrow at the right hand and where tho high frequenoies are controlled, and boing WIder at the left hend ond where the lowor frequencies are controlled. It is advantagoous to use such a slit Which makes the basic period of time maller for the hicher frequencies than for the lower frequencies.

The sound gonerator film 3 will in most cases be made with varying density along the film and usod in combination with a modulator film of the typo shown in Fig. 4 or 5. It is, however, possible to roverse the combination and use a modulator film of the variable density type shown in Tigure 5 , and a sound gonerator rilm on wich the frequencies are recorded by the variable width nothod.

It has boen mentionod that the number of the sections $\Delta x$ will be large and can be anything above 200 , for instance if the lowest frequency which it is desired to inelude in the reproduction is 100 , and the highest frequency is 5,000 , and if it is desired that the
difforence between two adjecent frequencies $v$ should be about $\Delta v=\frac{v}{100} ;$ i.e. $1 \%$ of the frequency it will be necessary to use about $N=\ln \frac{5000}{100} / \ln \left(1+\frac{\lambda}{100}\right)$ erequencies, $\ln \frac{5000}{100}$ is about $4 ; \ln \left(1+\frac{1}{100}\right) \simeq 0.01 ; \quad$ 1.e. $\mathbb{N} \simeq 400$.

Pigure 7 shovs the usual arrangement of transfoming the variations in the intensity of the iight (that enters the photocell) into sound. 6 is a photocell, 71 its cathode whioh is connected through a high resistance 72 to point 73. Point 73 is connected through a condeneer 74 to point 75 and point 75 is conneoted through a mall resistance 76 to the anode 77 of the photocell 6. Point 75 is comnected through a resistance 78 to the positive pole 79 of a high voltage battery B0. The negative pole 81 of this high voltago battery is connocted throuch a small battery 82 to point 78 and to the glowing filament 83 of a valve 85. The grid 84 of this valve is connected to the cathode 71 of the photocell. 6. The anode $\beta 6$ of the valve 85 is connected to one end of the pximary 37 of a transformor 88 the other end of the primary being connected to point 89. Point 89 is conneoted through a resistanco 90 to the positive pole 79 of the high voltage battery 80 on the one hand and through a condenser 91 to tho negativo pole 81 of the same high voltage battery on the other hand. The secondary 92 of the transformer 88 is connected to an amplifier set 93 which feods the loudspaakor 04.

Figure B shows an alternative form of apparatue for roprodueing sounds by the method according to the prosont invontion. 102 is a light source placed in the focus of the optical lons 102 which throws parallel IIght aeross the slit 104 and the sound genorator filn 203. A second optical lons 107 projects the image of the sound gonerating film 103 on the modulator 811 m 105 and the 12ght trananittod by 105 folls on the photocoll 106. A transparent glass plate 108 diverts somo 11ght by roflection at its surface and throws a faint imago of the filn 103 (in front of 104) through the dask filtor 100 on the photocoll 110. The purpose of the second photocoll 120 is the followings

For the recording of sound on the nodulator film 5 having variable donsity along the soctions $x$, it is somotimos dirricult to roach a vory high đonsity i.e. the transpaxency of tho seotions $x$ hae a very a vory suall though finite value even in the absonce of the corroaponaing frequencies in the music or speech which ia to be roproduced. Weak 11ght of all froquenoles thus roeches the photocell 206 in all oirounstances and would produce alsturbing sounds. The second photooo11 110 gets 11 ght airect fron the tound gonerator silm and the filtor 109 can be so adaptod that the current gonarated by 110 should for evoxy frequency oompensate the ourxent generated in 106 by the frequencies whioh it ta not aonirod to roproduco.

Figure 9 show: how the photocells 106 and 110 are used. 115 is a high voltage bettery, the positive pole 116 of which is connocted to the anode 117 of the cell 110 and the anode 118 of the cell 106. The cathode 119 of the cell 106 is comnected to point 120 and the cathode 121 of cell 110 is connected to point 122. The nogative pole 123 of the high voltage battery is connected to point 124 which is conneoted to the positive pole 125 of a small battery 132, the negative pole 126 of which is connected to point 227. Point 127 is connocted through a high rosistance 228 to point 120 (which is connected to the cathode 119 of the cell 106), and point 127 is also connoated through another high resistance 129 to point 122 (which is connected to the cathode 122 of the cell 110). Point 127 is conneeted through the condenser 130 to point 131 to which the positive pole 125 of the small battery 132 is also comnected (through point 124). Point 130 is connocted to the cathodos 133 of the valve 154 and 135 of the valve 136 . The grid 137 of the valve 134 is comnected to point 120 and the grid 138 of the valve 136 is connected to point 122. The anode 139 of the valve 134 is connocted to the ond 140 of the primary coil 141 of the transformer 142. The anode 143 of the valve 136 is connected to the other end 144 of the primary coil 141 . The middle 145 of the primary coil 144 is comnected to the positive pole 116 of the high voltage battery 115 . The secondary 146 ean be connected to an amplifier set and a loudspeaker.

If the recording of the sound on the modulator film 5 is porformed in a manner indioated in Figure 5 it is not necessary to have a limitod number of sactions $\Delta x$ isolated from oach other by blackened strips 51, 52, 53. Within each section $\Delta y$ the transparency of the film can bo a porfectiy continuous function of x . It hem is advantage of to use such a "smooth" modulator film in combination with a "smooth" sound generator film. We can got "smooth" sound genorator fllms in differont ways:

Figure 10 gives an indication of a "gmooth" sound genorator film. A sinus function of a certain wavelongth is photographed on section $x_{1}$ of the film (i.e, the transparency varies with $\underset{y}{ }$ along section $x_{1}$ according to $A\left(x_{1}\right) \operatorname{Sin} 2 \pi \mu(x) y ;$ another sinus function of a slightly airferent wavelength $\mu\left(x_{2}\right)$ is photographed on section $x_{2}$. Section $x_{1}$ and section $x_{2}$ axe overlapping as indioatod in Figure 10 . In the same way a third simus function is photographed on section x3, the Wevelongth $\mu\left(x_{3}\right)$ being again shiftod a little against the wavelength of section $x_{2}$. Section 3 is overlapping sections $x_{1}$ and $x_{2}$ in the mannor indiated in Figure 10. If light is admitted by the modulator film at a definite very narrow section of $X$ at a definite spot $X$ of the sound generator film, a sound will be produced which will contain a narrow band of frequencies, the contre of gravity of whioh will be detormined bv X. The breadth of the band depends on the breadth $D$ of the sections
$x_{1}, x_{2}, x_{g . \ldots . .,}$ on the shift $\epsilon$ of these sections with respect to each other, and on the shift of froquency $\frac{d \mu}{d x} \in$ from one section to another. The breadth of the band $v$ produced by light transmitted at a derinite spot X will approximetely be

$$
\Delta v=v \frac{d \mu}{d x} \in \cdot \frac{D}{\epsilon}=v \frac{d \mu}{d x} D .
$$

If it is desired to reproduce music it is important that the mean frequency $\sim$ generated by light transmitted at a derinite spot $\mathbb{Z}$ should be proportionel to e x ( $\frac{d \mu}{d x}=\alpha p$ ). If this condition is fulfilled ( $\mu=C e^{\alpha x}$ ) a mall shift of the modulator film with rospect to the sound generator film in the direction of the $x$ exis will not distort the music but only change the keyt for instance a fairly large shift would lad to the same musio being playod half a tono highor or lower. (It may be stated that the present system of sound reproduaing makes it possible to vary the tempi by varying the spoed of the modulator film without changing the speed of the sound generator fiIm ).

Ficure 11 indicates a special type of a "smooth" sound generator film, The two 11 nes 151 and 152 which are drawn parallel to the z axis across the film define a section Ye of the film which oorresponds to a certain length of time, say $1 / 10$ th to $1 / 40$ th of a second which may bo celled the basic length of time Tg of the sound generator film of this type. If $\overline{\text { is }}$ is velooity at which the sound gonerator film is moving then $\mathrm{VI}_{\mathrm{G}}=\mathrm{Y}_{\mathrm{G}}$.

The ine 154 indicates the middle of the section $\mathrm{Y}_{\mathrm{g}}$. The transparency of the film in the section $x_{1}$ is givon by a function $A x_{1} \cos \mu\left(x_{1}\right)\left(y-y_{0}\right), y_{0}$ boing the $y$ com ordinate of the midale of section Xg . This function is shown in Fisure 1la. The transparenoy of the film in the section $x_{2}$ (which is shifted in rospect of section $X_{1}$ by $\in$, and is overlapping soction $x_{1}$ ) is givon by a function $A\left(x_{2}\right)$ cos $\mu\left(x_{2}\right)\left(y-y_{0}\right)$, $\mu x_{2}$ being slightly different from $\mu\left(x_{1}\right)$. This function is shown in Figure 11b. The same applies to section $x_{3}$ and so on, The next section $\overline{Y g}$ between 1 ines 152 and 153 is made exactly like the section g between 151 and 152 ; again all the functions copied within this section $X_{g}$ have their maxima in the middle 255 of the section. The same holds for every following seotion Yg .

The boundaries of the sections $Y_{g}$ need not be perallel to the X axis, but con have a slight slope as indicated in Figure 12.

The basic length of time of the sound generator film may be a function of X the time being larger for the lower tones than for the higher ones. This is indicated in Figure 13.

Figure 14 shows another manner in which sound may be registered on the modulator PIIm 5 . The transparency of the film varies continuously (as a continuous function of X) across the film. This is brought about by having non-transparent and transparent lines running at $45^{\circ}$ to the $\underset{X}{ }$ axis across the film, the breadth of the transparent lines being a function of $x$.

Methods vill be doscribod whioh make it possible to manufacture one of the above mentioned types of modulator film from an oxdinary rocord of a piece of musio or of spooch on an oxdinary film , the sound boine rocordod in one of the two usual types of recording, 1.0. by efthor the variable width or variable density types.

In Figs. 15a and 15b is illustrated a mothod for transcribing this usual type of record into a sound record on the modulator film of one of the types montioned above. 160 is a film similar to the sound gonerator films as described above. 261 is the film on which a piece of music or speoch is rocorded in one of the two usual ways. The 11 ght onerging from the light source 162 placed in the focus of the optical lens 263, is rondered parallel theroby and thrown throuch a section $\mathrm{X}_{\mathrm{R}}$ of the sound gonerator PI 3 m 160 and of tho film 161. The length $Y_{R}$ corresponds on the rocord 161 to the basic length of time $T_{R}$ of the oporation of recoraing. While a certain soction of the rocord 161 is in front of the window 164, the film reoord 161 being at rest, the film 160 which will be called the "enalysor" is kopt moving. The light transmittod by the section $Y_{R}$ of both films is colloctod by the lens 165 and thrown on the photocell 166. As shown in Figuxe 15b tho window 164 admits only licht across a small section dx of the analyser. By ahifting the analyser in the airection of the $X$ axis different sections $X$ can be brought in front
of the window 264. with a given section of of the analysor (roprosonting a givon moan froguoncy $\mu(z)$ ) in front of the window 164 and with the analyser kopt moving in the direction of the y axis, while the film record 161 is at rost, the $11 \mathrm{ch}^{2}$ transmittod by tho tro filme will have a vaxying intonaity. The anplitude of the variation wili be detomined by the intensity of the oscilletion having the frequoncy $\mu(x)$ on the Piln record 161. Thorefore the amplitude of tho alternating curront generated by the photocell 166 will be dotermined by the intensity of the osciliation $\mu(x)$ on the filn reoord 161. If the altornating current genorated by the photoooll 266 is amplified and used to control the intonsity of a 11 ght sousoe 167 , the licht of which is throm through a slit 168 on a soction $d x$ of the $411 m 169$ the transparoncy of the soction dx will be deternined by the intonsity of the oscillation $\mu(x)$ on the xllm rocord 161. By shifting the film 169 togother with the analysor 160 parallel to the X aris, affeerent spots X of the enalyser axe broucht in front of the slit 264 and at the samo time difforont spote x of the Pilm 169 are brought In front of the slit 26. At aach section dx at the spot X of the rilm 169, the intensity of the eorresponding oscillation $\mu(x)$ on the 2113 recore 161 is thus rogistered. 160 or negatives of $1 t$ enn bo ueed as modulator film for our mothod of sound seproduction. The operation of transeription consiste of the repetition of two
alternative operations: the analyser 160 and tho record 169 are togother ehtetod forwards and backwards alone the $X$ oxis while the analyser ie rovolving fast and the filn record 161 and the record 169 are at a standstill. During this motion the rilm 161 is exposed to the 11 ght of the licht souree 267. The motion beine completed the film rocord 161 and the filia 169 are moved along the $Z$ sxis by a loneth comrosponding to a fraction, for instance $1 / 10_{2}$ of the basie length $Y_{R}$ of tho tranecription operation. Then 161 and 169 aro again shiftod forwards and backwards parallel to the 莫 axie wilo the 11cht souxce 167 acts on the 511 m 169 and so on. The curront gonerated by tho photocoll 166 may be amplified in any suitable mannor. In Fig. 16 is i11ustratod apparatue whereby recording may be carried out by moons of a Braun tube. Tho eloctrons omltted by the fllamont 176 of a Braun tube 175 are controlled by the cylinder 177 whtah is comnected to the negative pole 170 of a manll battery 179, the positive pole 180 of which is connected to the secondary winding 181 of a trunsformor 182. The othor pole of the socondary winding 181 is comnoctod to tho cathode 176, the prinaxy 185 of the transfomor being connocted to the anplifler of the slgnals from the cell 166 of Pig. 15a. The two onds of the filamont 270 are comnectod to the poles 184 and $1 \beta 5$ of the heoting battery 186, and the pole 185 is connected to the pole 187 of the high voltago battery 188. The positive pole 189 of the
battery 188 is connected to the anode 190 of the tube 275 . 191 is a luminescont sereen omitting light under the influence of the cathode rays, the intensity of the light being controlled by the amplitude of the alternating ourrent egenerated by the photocell. The tube 175 acts as rectifier in the same way as an audion. The battery 179 maintains such a voltage at the "grid" 177 that one halr cycle should get suppressed.

In the following another metrod of transcription will be described which only makes use of photographie methods. In Figs. 17a and 17b 200 is a light source placed in the focus of a lens 201 projecting parallal light on the analyser 202 and on the section $X_{R}$ of the film 203 on which the ploce of music or speech is recorded in one of the two usual ways of recording. A cylindrical lons 204 concentrates the $1 i$ ght transmitted by 202 and 203 on a small section dy of a film 205, which will bo called the first intermediary film. The light of each section $d x$ of the film 203 will be concontrated on the corresponding section dx of the first intemediary film. The films 203 and 205 are stmultaneously moved through the apperatue, both films moving for instance at the same speed. A. given section $d x$ of the film 205 may show aftor being developed a donsity indicated by the curve shown in Fig. 18. The period of oscillation shown in Fig. 18 corresponds to the period of the analyser in the corresponding section dx , and the amplitude of the osoillation shown in the density curve is determined by the amplitude of the oscillation of the corresponding frequency in the record
of spoech or musio on 211 203. Dy making a nogativo 810 (which w112 be callod the socond intomodiary efim) from the eflm 205 a donsity curve for the givon section ate of the nogntive may be obtainod as shom in Fig. 19. Fice 19 corresponds to the density curve of the xilm 805 thown in Tig. 18. In malting the nogativo the two films 210 and 205 aro hold apart at a cortain distance and tho light used for the copying is not striatiy parallel, but diverges within a plano which is perpondtcular to the film and parallel to the y axis. The divorgonoy should bo greatar for sections dx which correspond to lower tonos. If copying is done in this wey, tho negative 210 w111 not show the osel11ations of Figure 18 but only the mean valuos of the donality. This is inaicated in Figure 19.

If P11m 205 and its "blurrea" nogative 210 axe placed one on top of the othor and copled on a third silm 211 (which will be called the third internodiary P1Im) a hard copy can be obtained by using a suitable dovelopor suoh as one containing potassium biehromato. Tigure 20 shows such a copy thich corresponds to the extinotion eurves ghow in Figures 18 and 19.

Figuxe 21 shows how to transeribe the third intermediary film 211 into the modulator siln 212 which is neoded for the present system of reproduction. 280 is a light source placod in the focus of a lens 221 which mokes its light parallel and throves it across the slit 228 and the third internodiary $111 m 211$ on to the
film 212. Wile the film 211 is moving quickly the film 212 moves slowly and on a single saction ay of the 141m 212 in front of tho slit 228 a large number of fnaivitual humpe (shown in Tiguxe 19) of the f1lm 211 will be impressed.

Instaad of using a sound generator film as hitherto describod a sound genorator dise may be used in the manner illustrated with reforence to Tigs, 22 a and 22 b . 230 is the sound gonorator dise (a glass dise on whioh the oscillations are photographed). 231 is a slit the width of which can bo varied (and theroby the basic time of roproduction). In practice it is preforable to use a maller basie time for a quiok tempo, for instance allogro, and a larger basic time for andante. 232 is the modulator film.

In roproducing sound by the arrangement shown in Figure 1 oare must be takon that the width. y of the slit 4 should bo small enough in relation to the mallest wavalongth $1 / \mu$ photographed on the sound gonerator film 3. If it is đesired to use a widor slit $\Delta y, 1 / \mu$ oould bo inoreased, but this ile not very convenient for the following reasons if $1 / \mu$ is inoroased, the velocity Y at which the sound generator iflm moves must be increased in order to generate sound of the same frequency as before ( $\checkmark=v \mu$ ). It is thorofore better to use an amangemont shown in Tigure 23 whereby a larger $y$ may be used for the sme sound gonerator
film. In Figs, 23a and 23b thore is shown a light source 240 , the $1 i g h t$ of which is made paranlel by the lens 241 and thrown on the slit 243 , the width dy of which may be largor than the smallest wavelongth $1 / \mu$ on the cound genorator film if the arrangement as describod in the following is useds in front of the slit is moving the sound generator film 242 as described with reference to Figure 1, but there is another strip of film 244 fixed in front of the slit which is oxactly like the sound genorator 111 m 242 only at rest in front of the window. (Each individual section $\Delta x$ has the same valus of $\mu$ on both films 242 and 244.) The light transmitted by the slit 243 travarses the modulator film 245 and ontere the photocell 246. The current goneratod by the photocell may be used to operate a loudspoaker. The mothod for manufacturing the modulator film which has beon deseribed in Tigure 15 a and 15 b makes it necessary to have first an ordinary sound record on a film and to transeribe it eftervards into a record (the modulator film) as required by the present system of sound reproduction. In Tigs. 24e and 24 b is illustrated a direct method of obtaining the modulator film which has the great edvantage that an ordinery sound film (which is very long as compared to the modulator filmineed not be mado.

250 is a cathode.tube, the intensity of the cathode rays emerging out of the window 251 of the cathode tube
being controllod by moans of the exid 252 by a nierophone (the speech or masic acting airoctiy on the merophono). The cathode raye 253, the intenalty of which follow the oscinlations of tho sound, strike a rotatine disc 258 at Its oylindrical efrounforence 255 which is coated by a Iuntnescent phosphor. For this purpose a phosphor is chosen wioh has a surficiontly long after-glow. If the volocity of the periphory of the dise ia of the order of 2. metre per second the 11ght onfttod by tho phosphor in front of the lens 256 ghould at1 11 be strong onouch to porntt photographic rocording in tho procens described bolow. The lene 256 projocte the image of the section 257 of the pariphory of the diac 254 on the alit 250. An analyser 250 formed in the same wey as sound generator films axo formod, is kopt rapidly moving in front of slit 258 in such a voy that many waves rocorded on the analysor 259 pass soxose the alit 258 while the dise 245 moves \& distance which is only a sraction of the corresponding wavolongth (the voloeity of 259 is large as comparod to tho volooity of 255). On the suxiface 255 the Iuninosity Is conatont an a function of tho X oo-orainote and a function of the $z$ co-oxdinate which ahow the osolilations of the sound. The seotion 257 bears a recosd of the sound to be recorded similar to that of an oxdinary sound rilm, for instance as in Iigure 15. A mirror 260 in front of the alit 258 projects the image of the slit on a photocell 261. The mirros osocilatos
rapialy about the axis 862 , thereby projecting one seotion Qx after another on the photocell 261. The oscillations or the mirror 260 are slow in comparison with the oscillations of light generated by the motion of the analyser, but quick in comparison with the motion of the disc 254. The photocell 261 controls a cathode tube 263 In the same way as deseribed with reference to Figure 15. The luminous spot of the cathode tube 263 is projected by the mirror 264 on the Pilm 265. The mirror 264 oscillates about the axis 266 in synchronism with mirror 260 so that When mirror 260 projects the image of a definite section $Z$ on photocell 361 , mirror 264 should project the image of the luninous spot of tube 263 on the corresponding section x of film 265.
Dated this day of 1935.

Agents for the applicants,
6, Breara's Duildings, London, E.C. 4.


[^0]:    In the following another method of transcription

