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

(a) I (or We) Leo Szilard
Strand Palace Hotel, Strand, London W.C.
a subject of Hungary and citizen of Germany

10516

6 APR 1934

do hereby declare that I am (or we are) in possession of an invention the title of which is (b) Reproduction of Sound

(b) Here insert title of invention.

that (c) y claim......to be the true and first inventor......thereof, and that the same is not in use by any other person or persons to the best of my (or our) knowledge and belief; and I (or we) humbly pray that a Patent may be granted to me (or us) for the said invention.

(c) State here who is or are the inventor or inventors.

Dated the 5th day of April, 1934.

(d) Leo Szilard

(d) To be signed by applicant or applicants and, in the case of a Firm, by each partner.

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to act for me (or us) in respect of the within application for a Patent, and request that all notices, requisitions, and communications relating thereto may be sent to him (or them) at the above address.

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I (or We) hereby request that all notices, requisitions, and communications in respect of the within application may be sent to

Miss Simpson, 6 Halliwick Rd

Muswell Hill at* London N. 10.

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Dated the 5th day of April, 1934

† Leo Szilard

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PATENTS & DESIGNS ACTS, 1907 to 1932.

14

PROVISIONAL SPECIFICATION.

(To be furnished in Duplicate.)

(a) Here insert title verbally agreeing with that in the application form.

(a) Reproduction of Sound.

10516

6 APR 1934

(b) Here insert (*in full*) name, address and nationality of applicant or applicants as in application form.

(b) I (or We) Leo Szilard Strand Palace Hotel, Strand, London W.C., a subject of Hungary and citizen of Germany

do hereby declare the nature of this invention to be as follows :—

(c) Here begin description of the nature of the invention. The continuation of the specification should be upon wide-ruled paper of the same size as this form, on one side only, with a margin of one inch and a half on the left-hand part of the paper. The specification and the duplicate thereof must be signed at the end and dated (thus): "Dated the day of 19 ."

(c)

Omit

Reproduction of Sound.

The invention concerns a method for registering sound, for instance speech or music by photographic methods for instance 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 Δy of the film 5. which is in front of slit 4, but also a quickly moving film 3, the sound generator, which is continuously revolving in itself and passing in front of slit 4. An optical lens 2 makes the light of the light source 1 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.

In figure 2 you see two ~~pieces~~ strips of the films 5 and ~~strips~~ 3 which move past each other. ~~drawn below one another.~~ The upper film strip 5 is the modulator film. The section Δ y which is in front of the slit 4 corresponds to a period of time of 1/10 to 1/40th of a second, that is to say that in 1/10 to 1/40th of a second the section Δy passes the slit 4, and after that time a new section Δy of the modulator film will be in front of the slit 4. This period of time (which may be 1/10th to 1/40th of a second) will be called the time basis of the reproduction. If one goes within the section Δy from left to right across the film 5 one passes 11 sections Δx and the transparency of each section (the amount of light each section will allow to pass) determins the composition of the sound which is produced by the film 3 at the time when the section Δy 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 Δx 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 Δy. Such a curve is shown in figure 3. It gives the frequency spectrum of the sound at a definite moment (within a certain basic period of time, the time basis of the reproduction). x need not be a direct measure of the frequency, but the frequency is a function of x ($\nu = f(x)$) the form of which can be chosen to suit certain requirements. The film 3 in figure 2 is also divided into 11 sections Δx at (x_1, x_2, x_3, ... x_{10}). Within each of these sections Δx 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 Δx to another, A being a function of x. Of course μ varies also from one section Δx to another, μ being a function of x.

If the film 5 would remain fixed, a given section Δy

being in front of the slit 4, and if the film 3 ~~would be~~ moved past the slit 4 with a velocity v one would hear a sound composed of 11 frequencies i.e. the frequencies $v\mu(x_1); v\mu(x_2); v\mu(x_3); \ldots v\mu(x_{11})$ 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 ~~definite~~ sections Δx 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 1/40th of a second another section Δy 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 Δx) 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 Δx has a transparent section surrounded by two non-transparent sections. The amount of light transmitted by section Δx 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 non-"transparent" sections. The breadth of the "transparent" section is constant along the film (it 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 varies along the film.

If the slit 4 has a width of 1/10 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 ~~need~~ require 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 1/40 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. or 5. 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 Δx is created by a transparent section within each section Δx, the width of the said transparent section varying with y.

~~Of course a sound~~ SIC. generator film of SIC. the first mentioned type can be used also in combination with a modulator film of the ~~type shown in figure 5~~ SIC.

It has been mentioned that the number of the sections Δx 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 $\Delta\nu$ should be about $\Delta\nu = \frac{\nu}{100}$; i.e. 1% of the frequency, we shall have to use about $N = \ln\frac{5000}{100} / \ln(1+\frac{1}{100})$ frequencies. $\ln\frac{5000}{100}$ is about 4; $\ln(1+\frac{1}{100}) \cong 0{,}01$; i.e. $N \cong 400$. SIC.

SIC. SIC.

Figure 7 shows the usual arrangement of transforming the variations in the intensity of the light (~~falling on~~ that enters SIC. 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 connected to the cathode 71 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 positive pole 79 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 1, 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 image 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 surface and throws a faint image of the film 103 (in front of 104) through the dark filter 109 on the photocell 110. The purpose of 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 Δ x has, though a very small, yet a finite value ~~even~~ in the absence of the corresponding frequencies in the ~~sound~~ music or speech which ~~ought to be recorded~~ is to be reproduced.
If the second photocell were not present weak light of all frequencies would reach photocell 106 in all circumstances, and would produce disturbing sounds. If one uses a

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 Δx of the sound modulating film 105 has its minimum value (which signifies the absence of the corresponding ~~sound that has to be recorded)~~ frequency in the music or speech recorded on film 105).

Figure 9 shows how the photocells 106 and 110 are used. 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 cathode119 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 battery 132, the 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 cathode 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 ~~xxx~~ cathodes 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 can 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 Δ x which are isolated from each other by blackened strips 51, 52, 53 .... . Within each section Δ 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 (i.e. the transparency varies with y along section x_1 according to $A(x).\sin 2\pi u(x) y$); another sinus function of a slightly different wave length $1/u(x_2)$ is photographed on section x_2. Section x_1 and section x_2 are over-lapping as indicated in figure 10. In the same way a third sinus function is photographed on section x_3, the wave length $1/u(x_3)$ being again shifted a little against the wave length of section x_2. Section x_3 is over-lapping sections x_1 and x_2 in the manner indicated in figure 10. If light is admitted by the modulator film at a definite very narrow section dx at a

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 D of the sections 1, 2, 3 .... , on the shift ε of these sections with respect to each other, and on the shift of frequency $\frac{d\mu}{dx}\varepsilon$ from one section to another. The breadth of the band $\Delta\nu$ produced by light transmitted at a definite spot x will approximately be

$$\Delta\nu \cong v\frac{d\mu}{dx}\cdot\varepsilon\cdot\frac{D}{\varepsilon} = v\cdot\frac{d\mu}{dx}\cdot D$$

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 $e^{\alpha x}$ ($\frac{d\mu(x)}{dx} = \alpha\mu$). If this condition is fulfilled ($\mu = c_1 e^{\alpha x}$), a small shift of the modulator film with respect to the sound generator film in the direction 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 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 of the film which corresponds to a certain length of time say 1/10 to 1/40th of a second which we will call the basic length of time T_g of the sound generator film of this type.[1] The line 153

[1] If v is the velocity at wich the sound generator is moving, then $v \cdot T_g = Y_g$

indicates the middle of the section Y_g ~~Y~~ SIC The transparency of the film in the section X_1 is given by a function $A(x) \cos \mu(x_1)(y - y_0)$; y_0 the y co-ordinate of being/the middle of section ~~Y~~/ Y_g. SIC SIC SIC

This function is shown in figure 11a. The transparency of the film in the section X_2 (which is shifted in respect of section X_1 by ε, and is over lapping section X_1) is given by a function $A(x_2) \cos \mu(x_2)(y - y_0)$ $\mu(x_2)$ being ~~shifted~~ slightly different from $\mu(x_1)$. This function is shown in figure 11b. The same applies to section X_3 and so on.

The next section Y_g between 152 and 154 is made exactly alike the section Y_g between 151 and 152; again all the functions copied within this section Y_g have their maxima in the middle of the section ~~152~~ 155. The same holds for ~~the~~ every following section Y_g.

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 non-transparent and transparent lines running at 45° 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

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 film on which a piece of music or speech is recorded in one of the two usual ways. The 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_R of the sound generator film 160 and of the film 161. The length Y_R corresponds on the record 161 to a certain length of time T_R, the basic length of time of the operation of recording ~~transcription~~ ( ) While a certain section of the record 161 is in front of the window 164, the film record 161 being at rest, the film 160 which will be called the "analyser" is kept moving. The light transmitted by the section Y_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 dx 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 dx of the analyser (representing a given mean frequency $\bar{u}(x)$) in front of the window 164, and with the "analyser" 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 $\bar{\mu}(x)$ on the film record 161. If the alternating current 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 dx of the film 169 the transparency of the section dx 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 164 ~~together with~~ and at the same time different spots x of the film 169 are brought in front of the slit 168. At each section dx at the spot x of the film 169, the intensity of the corresponding oscillation $\bar{\mu}(x)$ on the film record 161 ~~is registered~~ 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 standstill as well as the record 169. ~~Then as a next step~~ During this motion the film 161 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 instance 1/10 of the basic length ~~of time~~ Y_R of the transcription operation (for instance 161 is ~~shifted~~ 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 which is connected ~~through~~ to the negative pole 178 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 cathode 176, the primary 183 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 to the 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 ~~xxxxxxxx~~ such a voltage at the "grid" 177 that one half cycle should get surpressed.

In the following another method of transcription 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 201 projecting parallel light on the analyser 202 and on the section Y of the film 203 on which the piece of music or speech is 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 dx of the film 203 will be concentrated on the corresponding section dx 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 dx of the film 205 may 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 dx, 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 record of speech or music on film 203. By making a negative (210 which will be called the second intermediary film) from the film 205 we obtain an extinction curve for the given section dx 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 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 figure 18 but only the mean values of the extinction. This is indicated in figure 19.

If film 205 and its "blurred" negative 210 are placed one on top of the other[x] and copied on a third film 211 (which will be called the third intermediary film) one can get, by using a developer containing potassium ~~bromide~~ bichromate, 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 shows how to transcribe the third intermediary film 211 into the modulator film ~~203~~ 212 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 ~~across a section Y (which can correspond to 1/10 to 1/40th of a second) of the film 211. A cylindrical lense 223 concentrates the light on a small slit 224 in front of which the film 205 is moving along. The light of each section dx on the film and of slit the instrument~~ on the film ~~203~~ 212. While the film 211 is moving quickly the film ~~202~~ 212 moves slowly and on a single section dy of the film ~~202~~ 212 in front of the slit 222 a large number of individual humps (shown in figure ~~19~~ 20) 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

[x] Fig 19a shows how the intensity of the light varies after passing both films 205 and 210

as shown in figure 22.

In figure 22.230 is the sound generator disc (a glass 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 tempi for instance allegro and a larger basic time for andante. 232 is the modulator film.

In reproducing sound by the arrangement shown in figure 1 one must take care that the width Δy 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 Δy one could increase $1/\mu$ but this is not very convenient for the following reason: if we increase $1/\mu$ we have to increase the velocity v at which we move the sound generator film in order to generate sound of the same frequency ν as before ($\nu = v\mu$). It is therefore better to use an arrangement shown in figure 23 which enables us to use a larger Δy 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 Δx have (sic) the same μ on both films 242 and 244.)

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 15a and 15b 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 24 250 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 microphone). The cathode rays 253, 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 of the disc 254 on the slit 258. An analyser 259, built in the same way as sound generator films are built, is kept rapidly moving in front of slit 258 in such a way that many waves ~~even of the longest wave lengths~~ recorded on the analyser 259 enter the slit 258 while the disc 245 moves only by a fraction of the corresponding 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 ~~xxx~~ one section dx 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 ~~to~~ mirror 260 so that when mirror 260 is projecting the image of a definite ~~fraction~~ section x on photocell 261, mirror 264 should project the image of the luminous spot of tube 263 on the corresponding section x of film 265.

London, this day of Apr. 5th. 1934

Leo Szilard

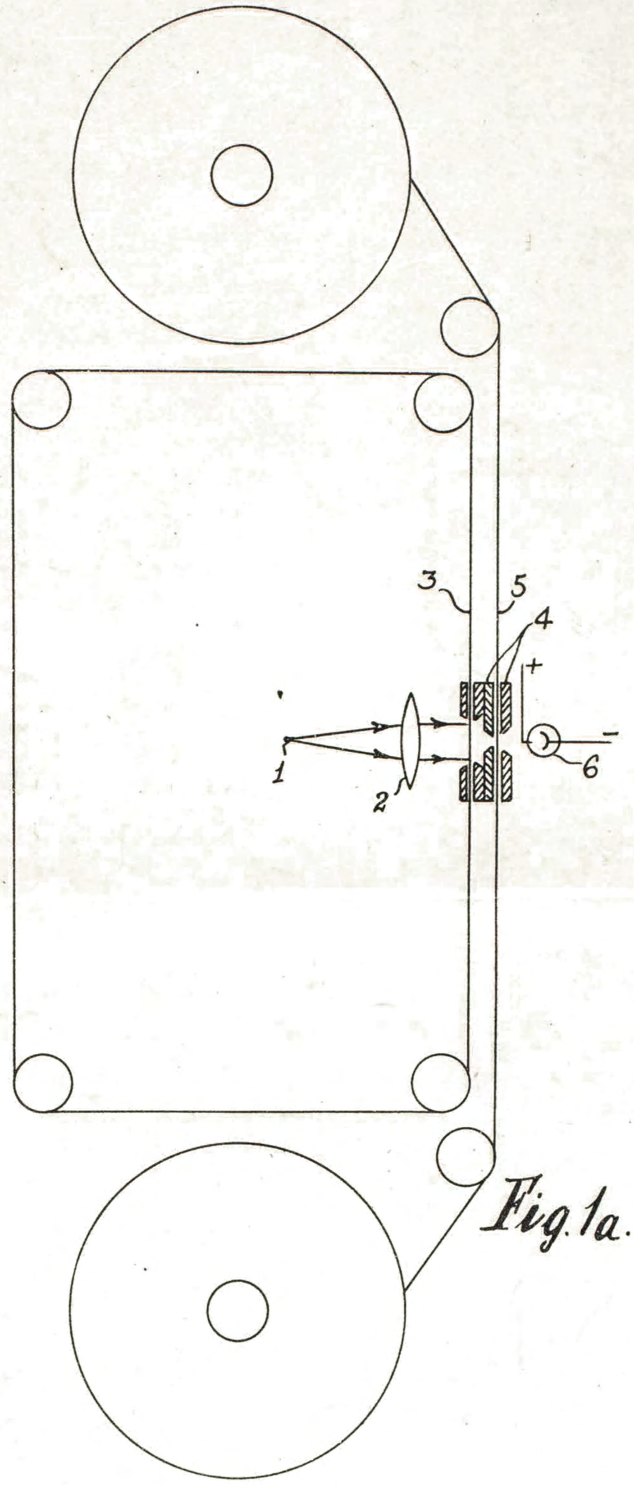

Fig. 1a.

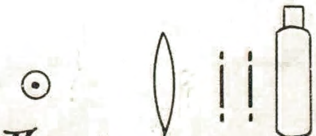

Fig. 1b.

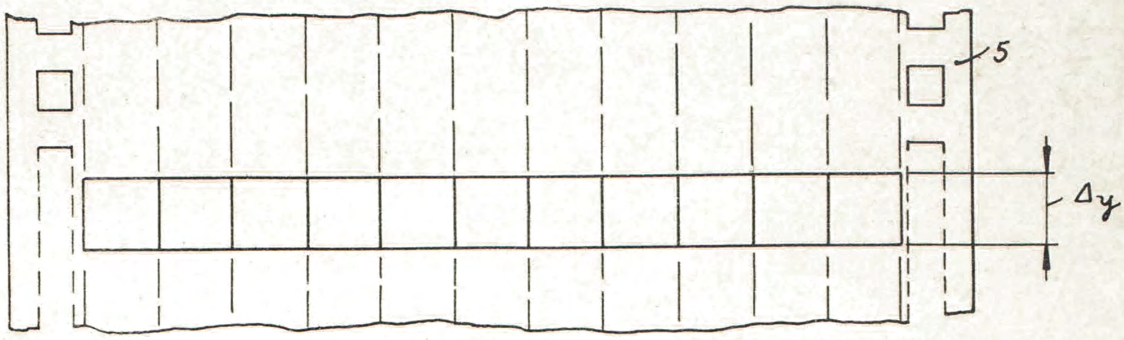

Fig. 2a.

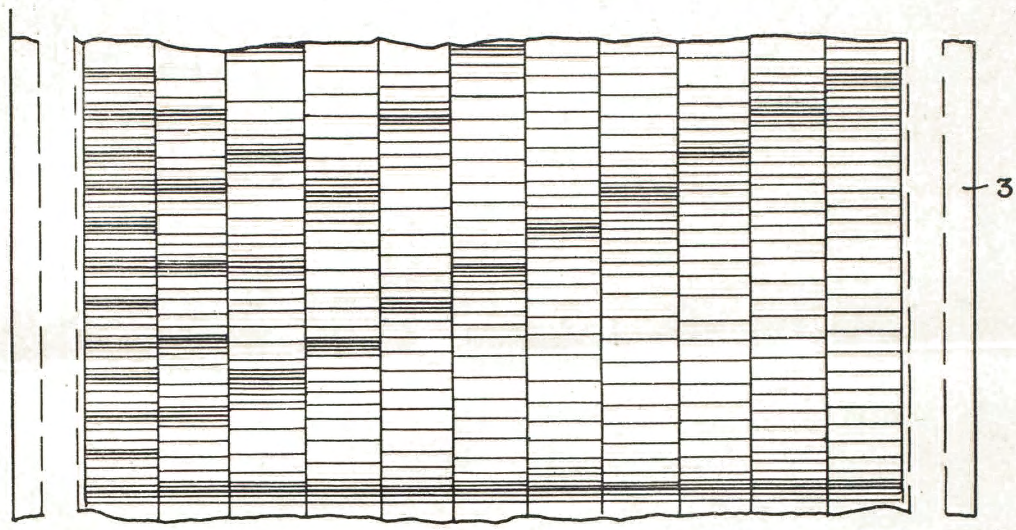

Fig. 2b.

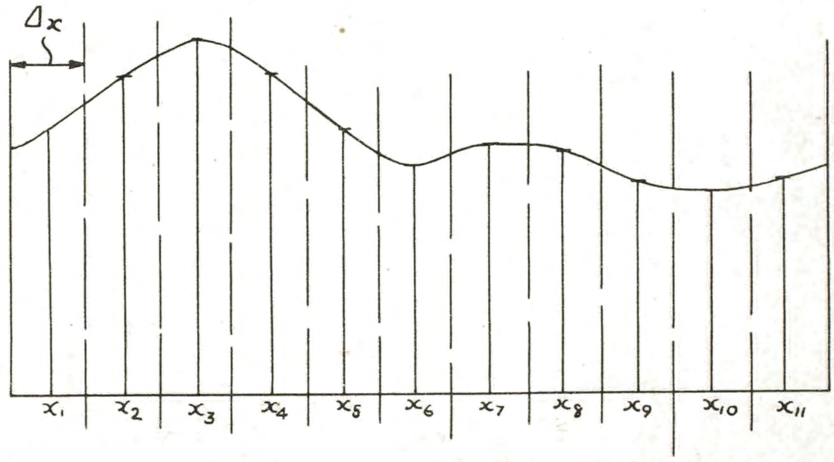

Fig. 3.

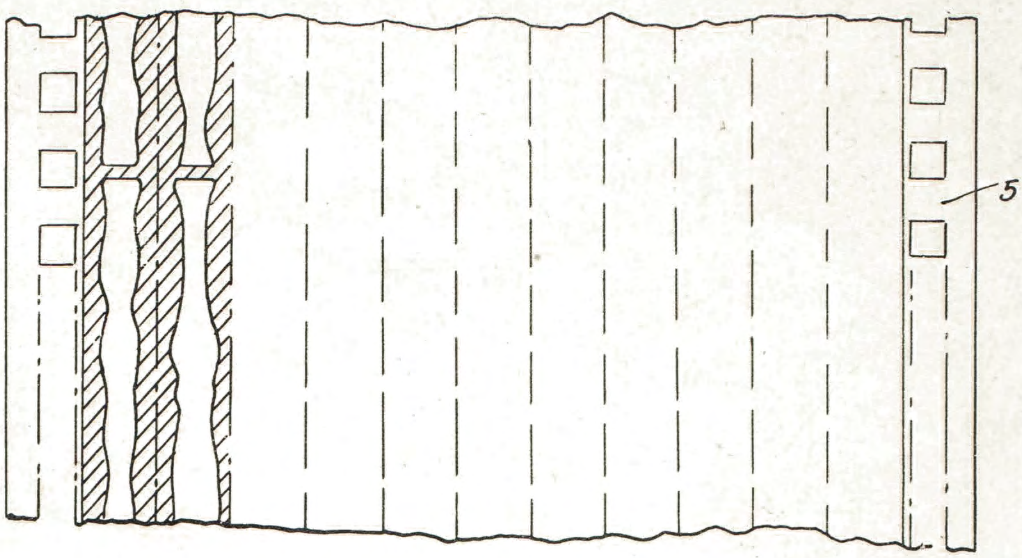

Fig. 4.

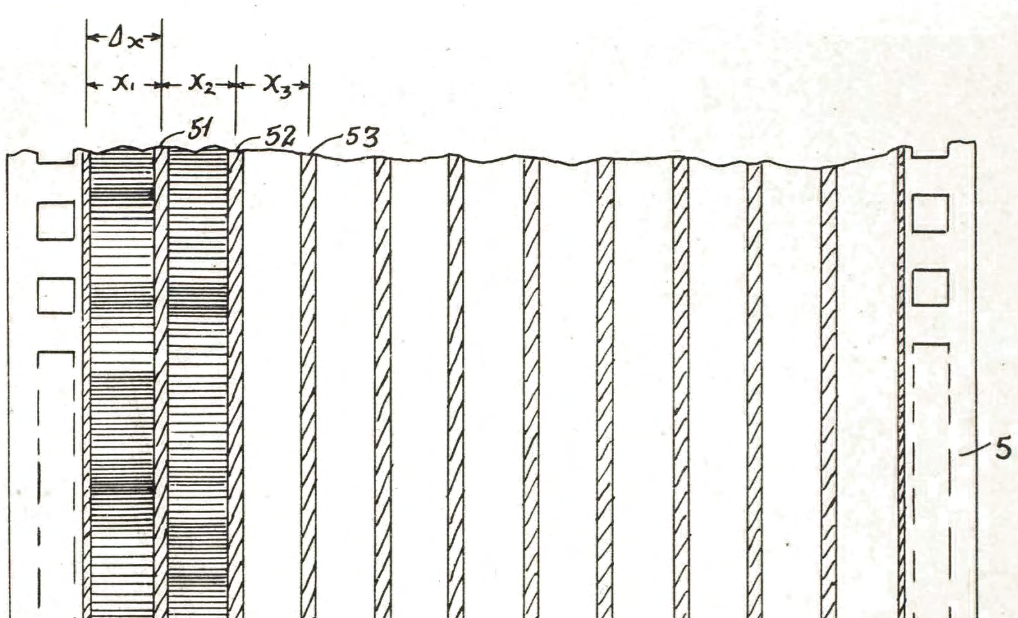

Fig. 5.

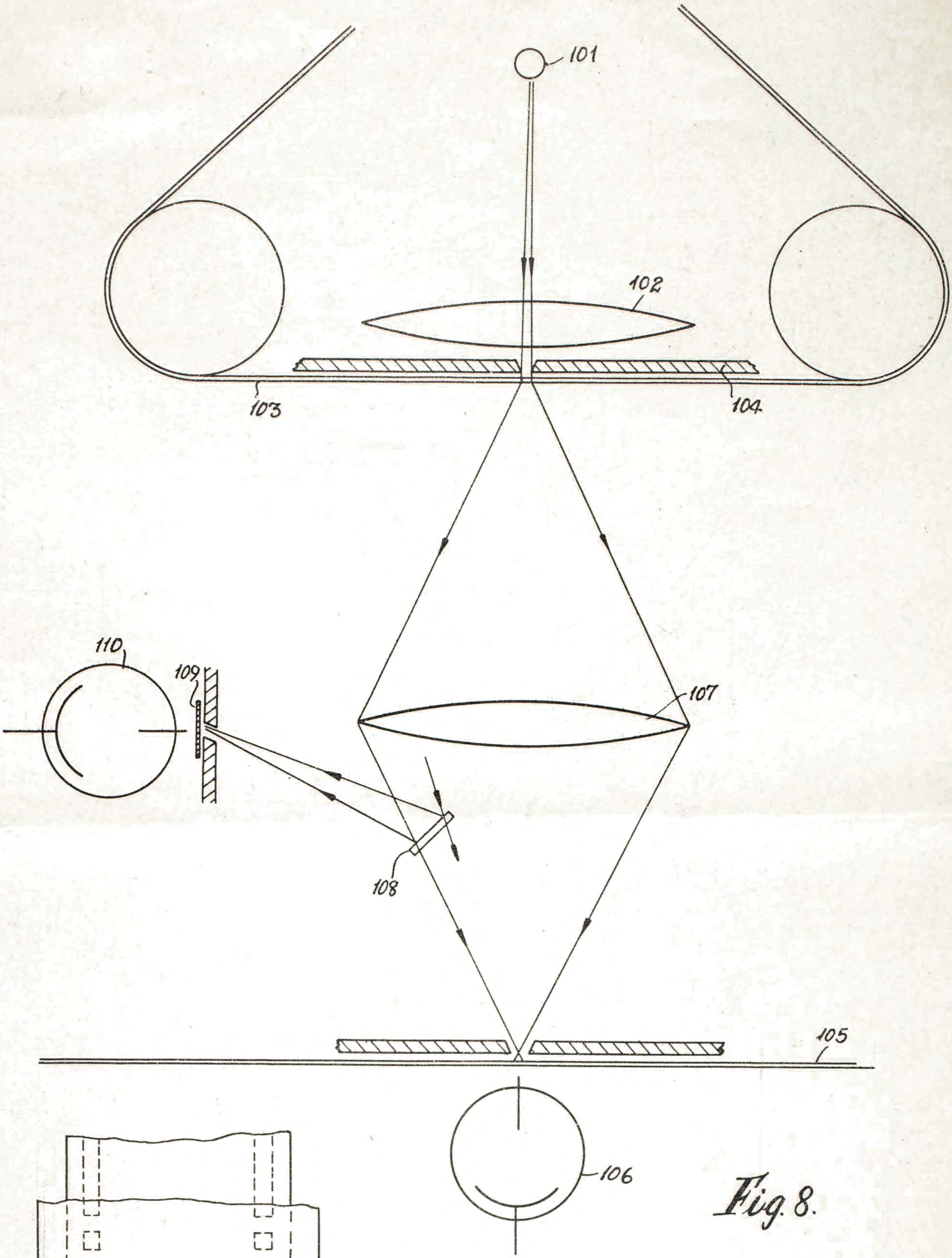

Fig. 8.

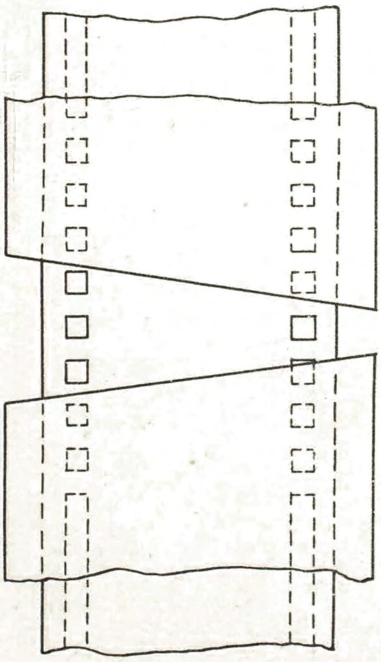
Fig. 6.

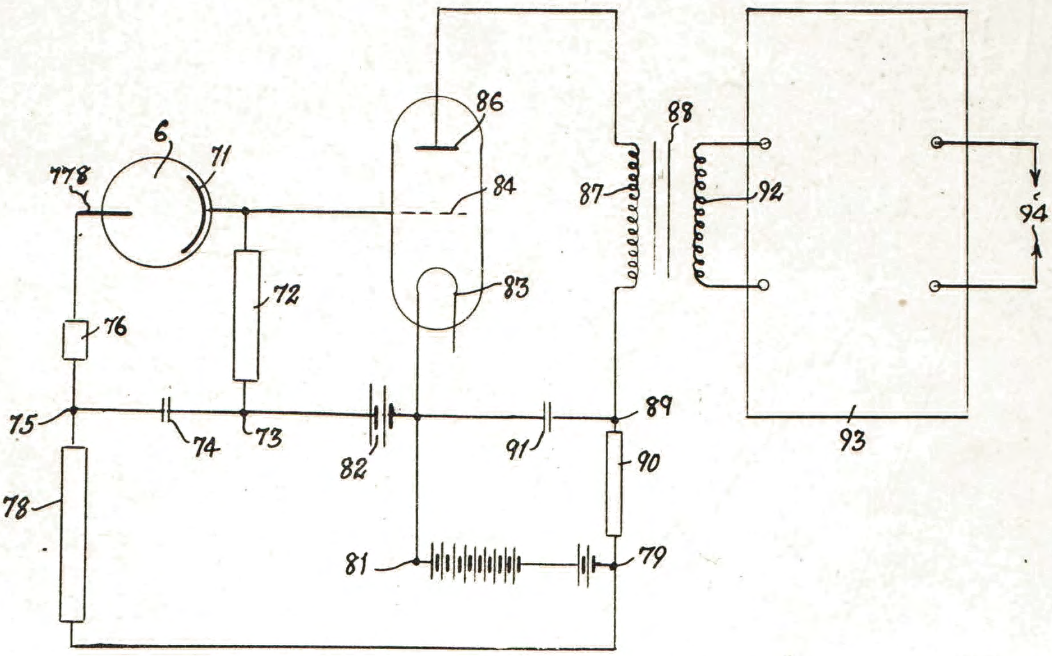

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Fig. 7.

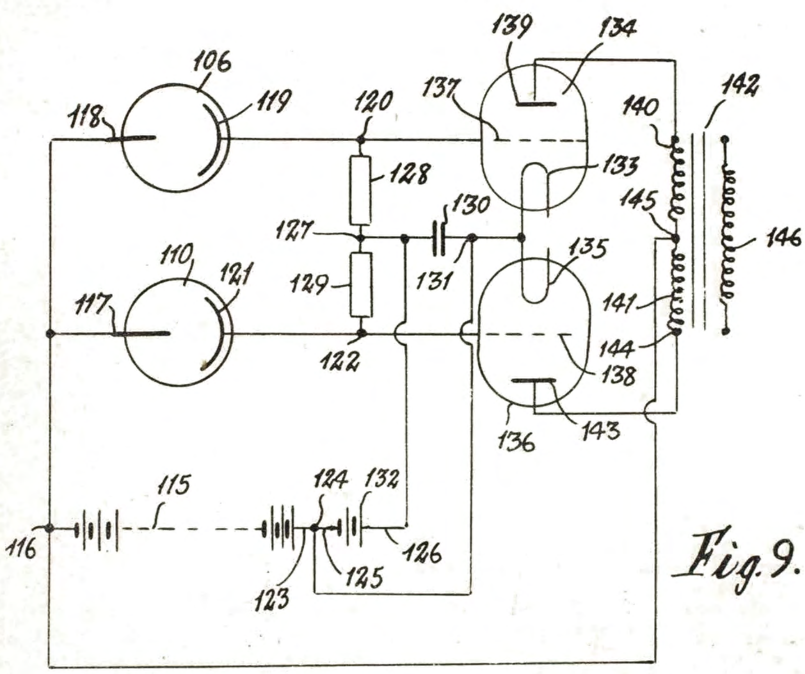

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Fig. 9.

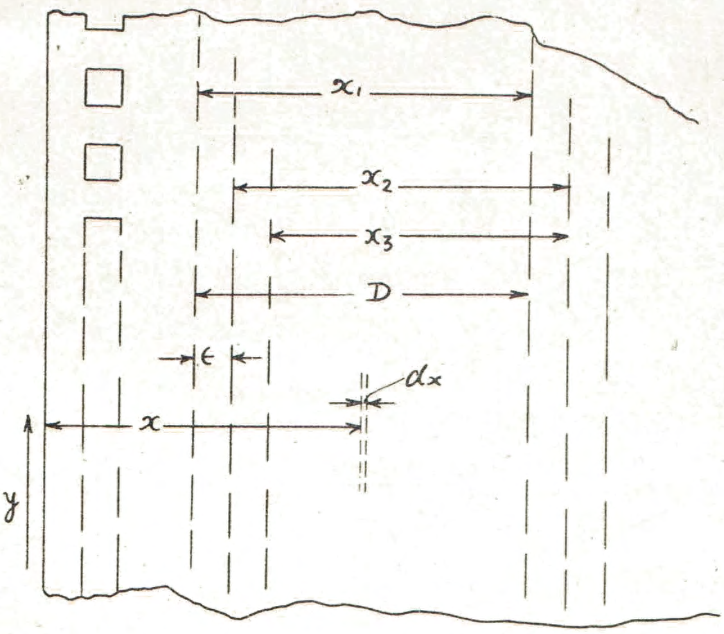


Fig. 10.

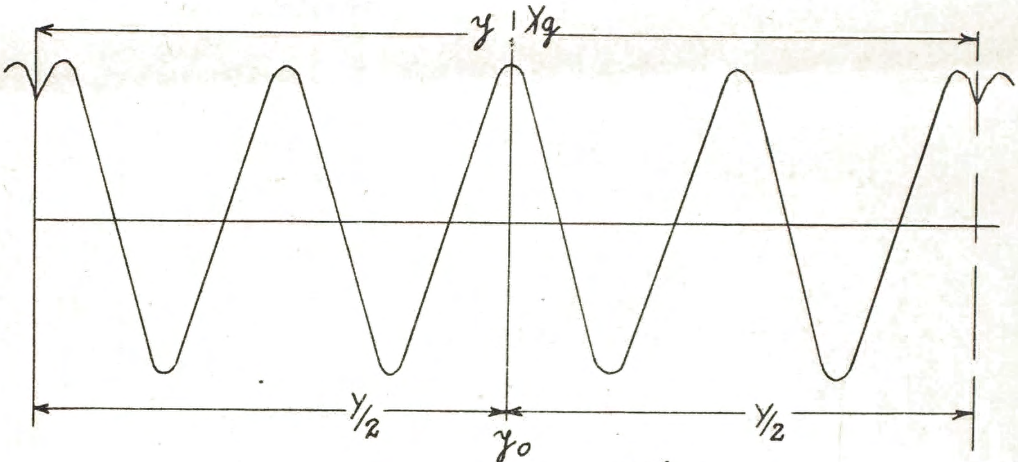


Fig. 11a.

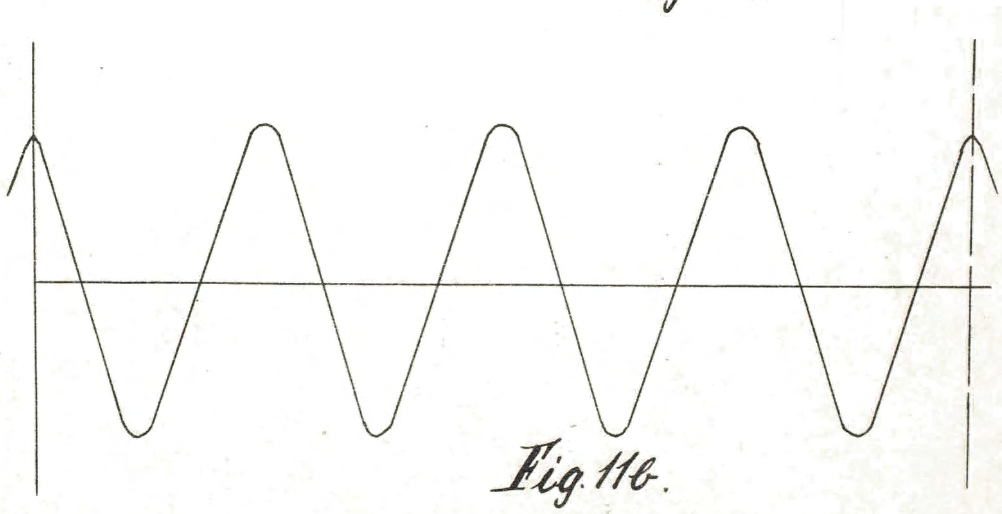


Fig. 11b.

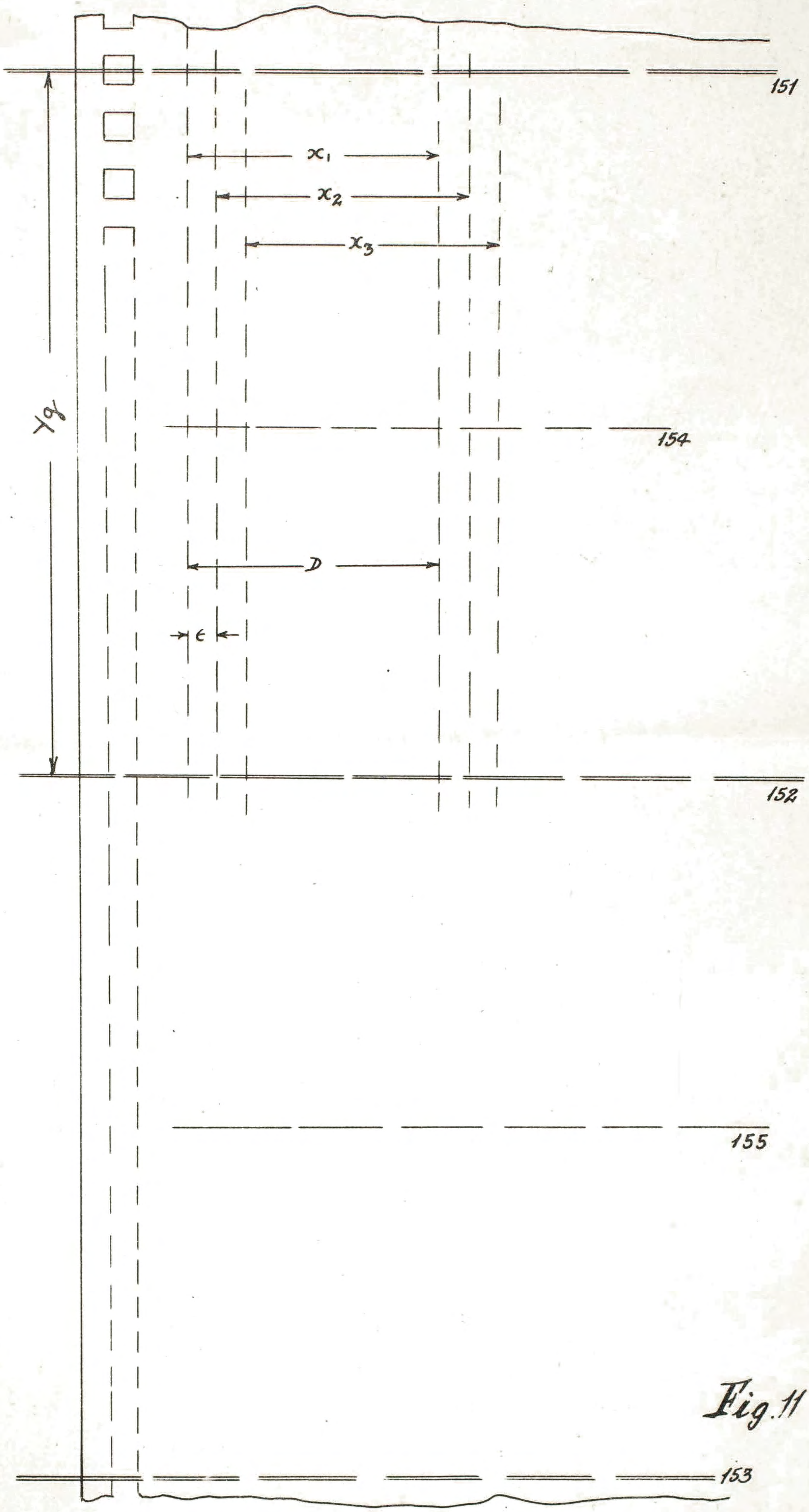


Fig. 11

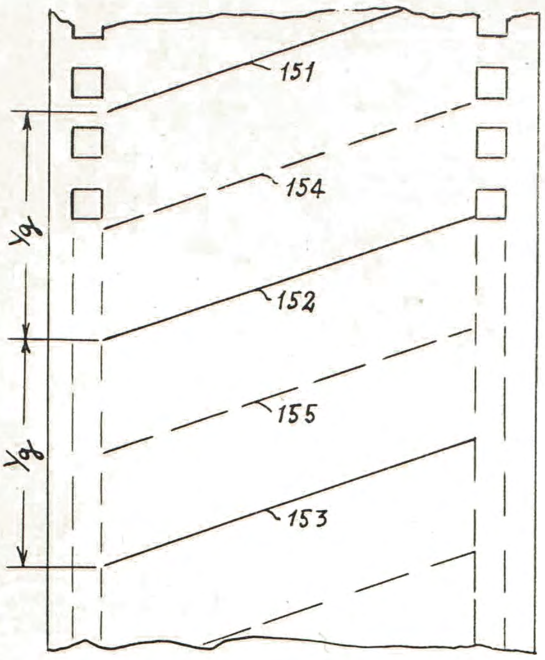


Fig. 12.

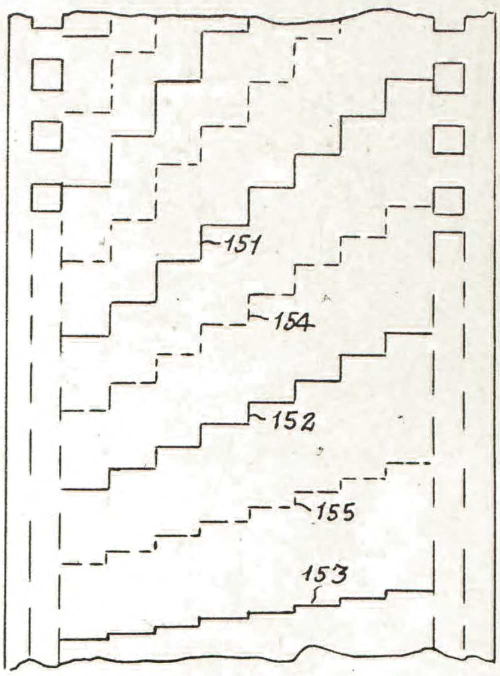


Fig. 13.

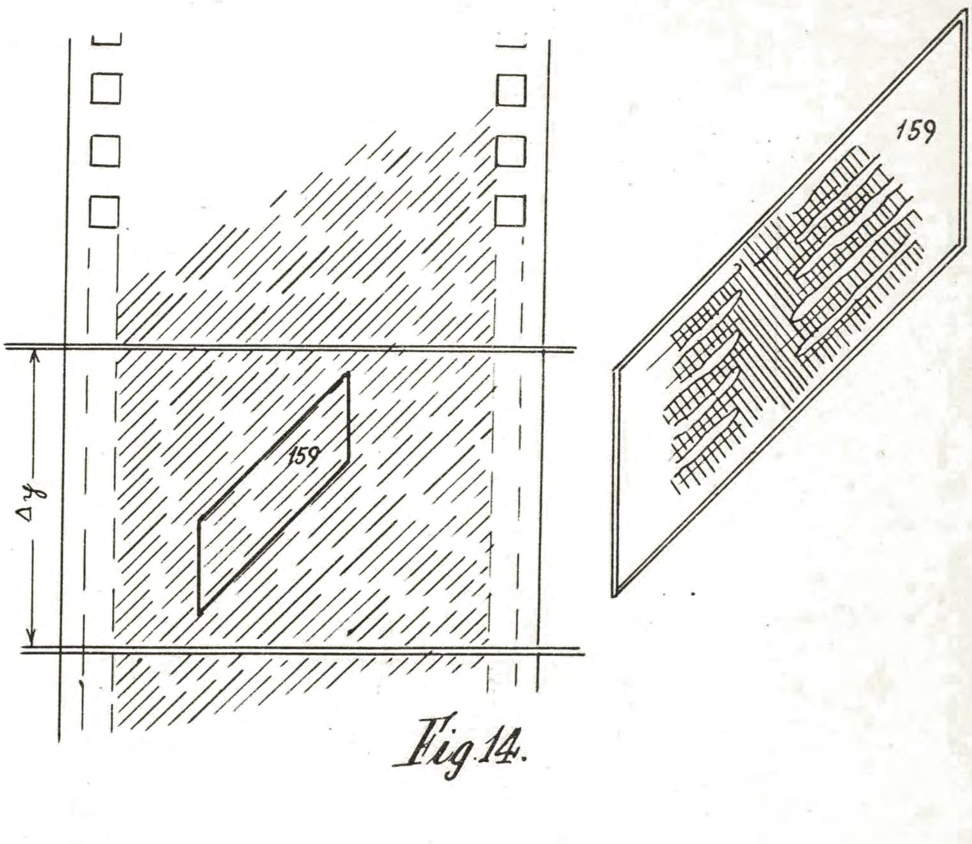


Fig. 14.

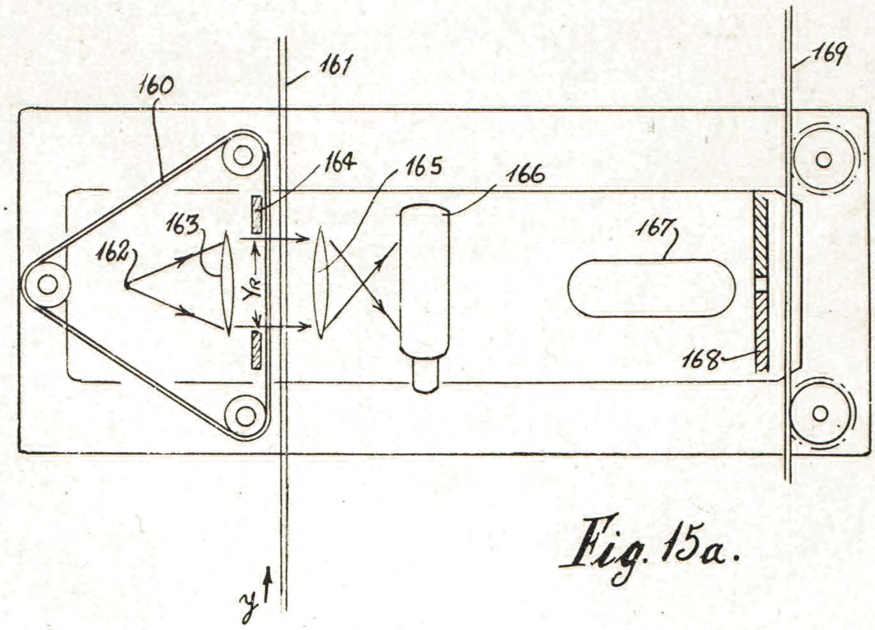


Fig. 15a.

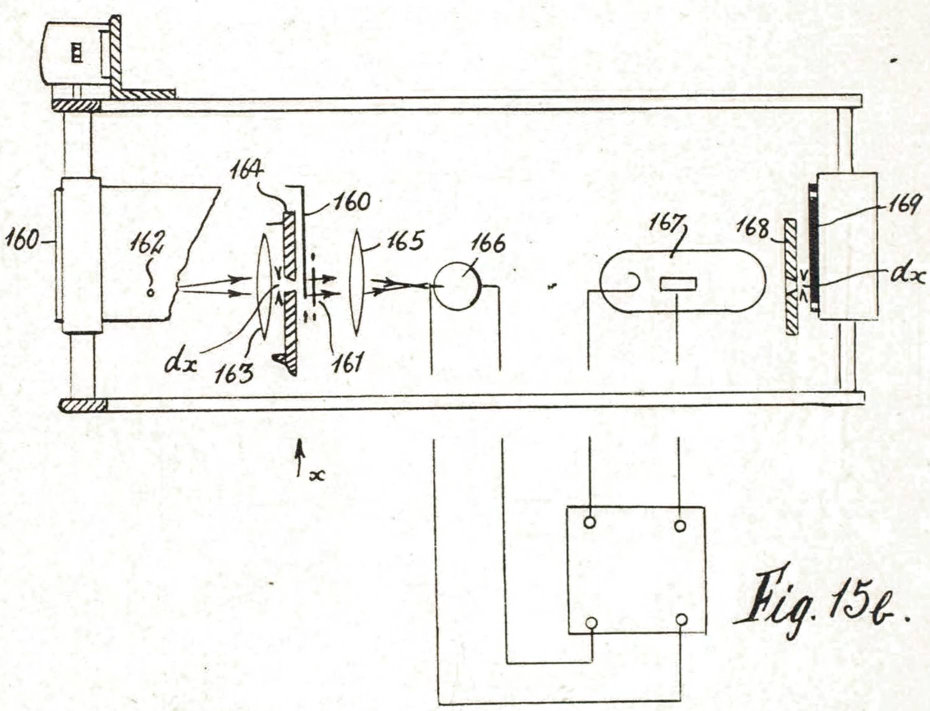


Fig. 15b.

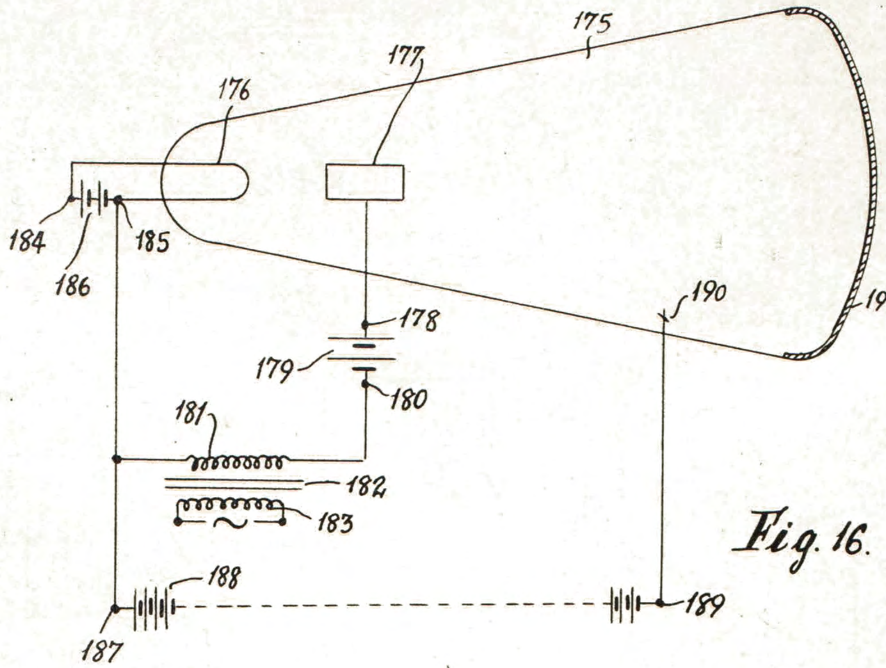


Fig. 16.

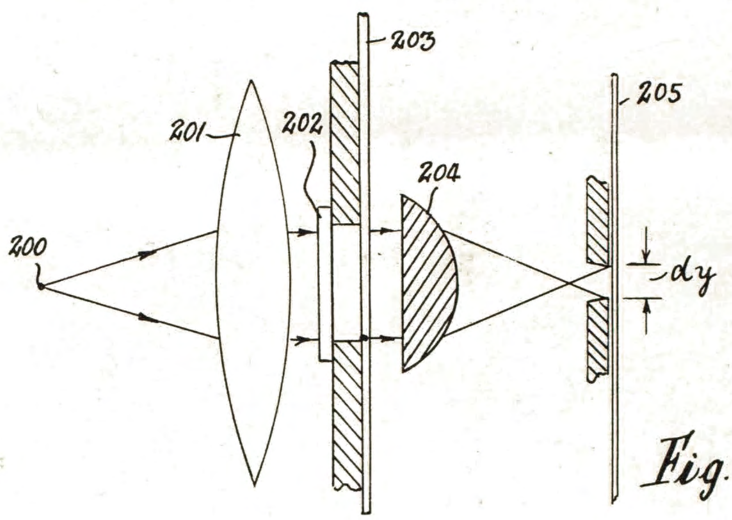


Fig. 17a.

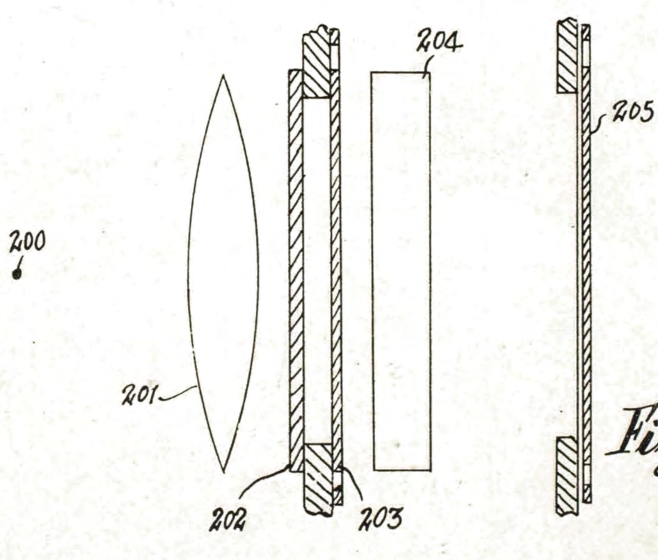


Fig. 17b.

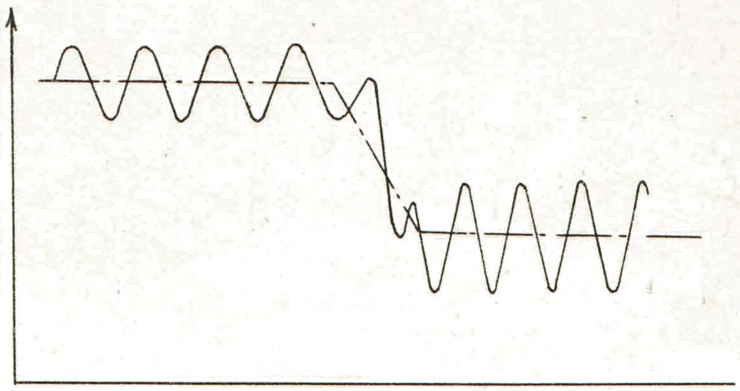


Fig. 18.

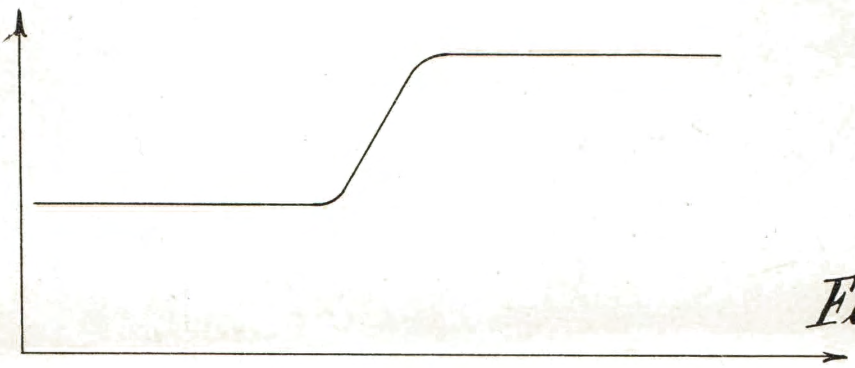


Fig. 19.

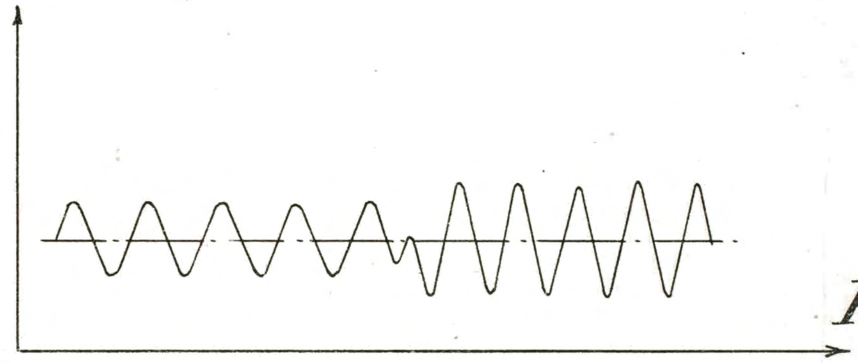


Fig. 19a.

Fig. 20.

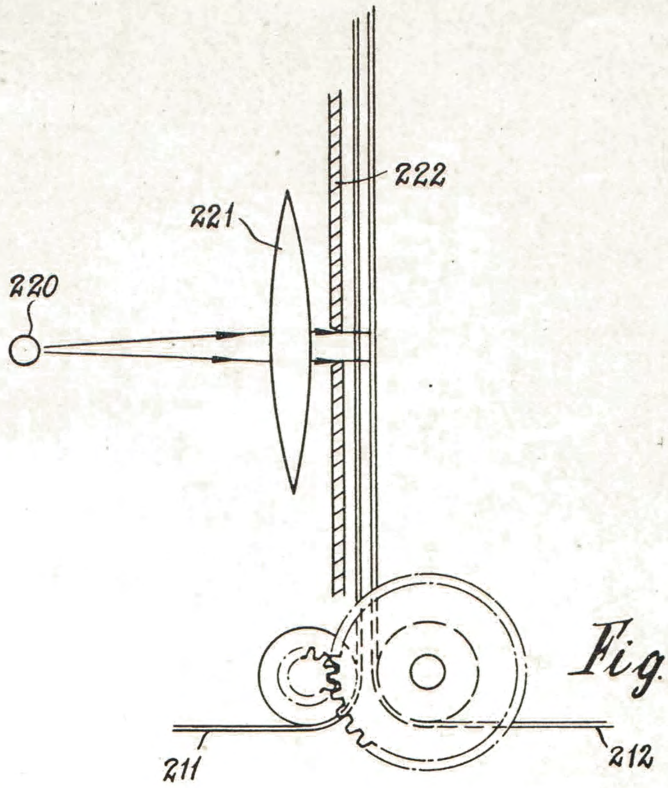


Fig. 21.

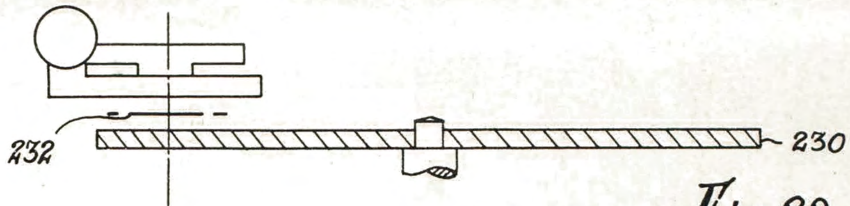


Fig. 22a.

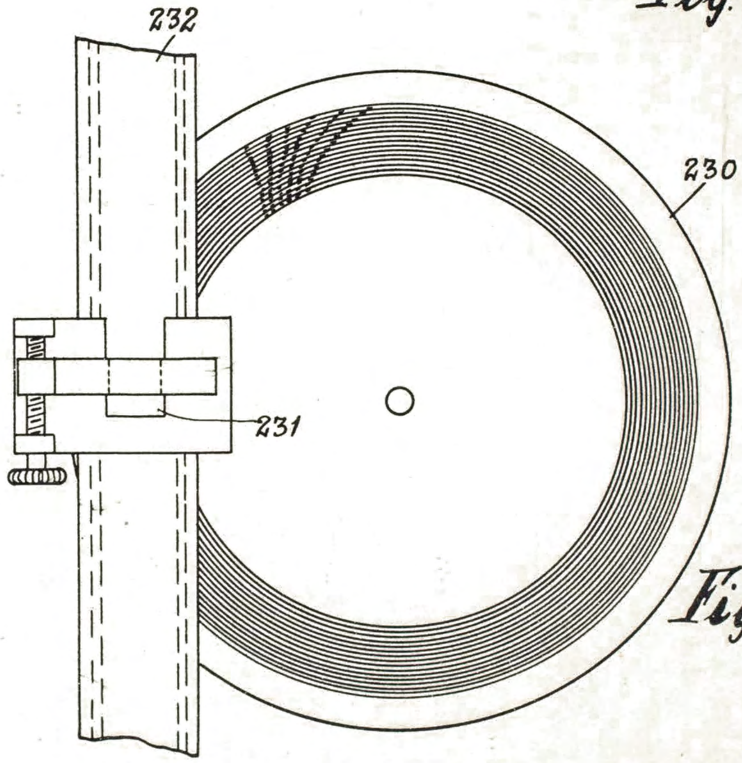


Fig. 22b.

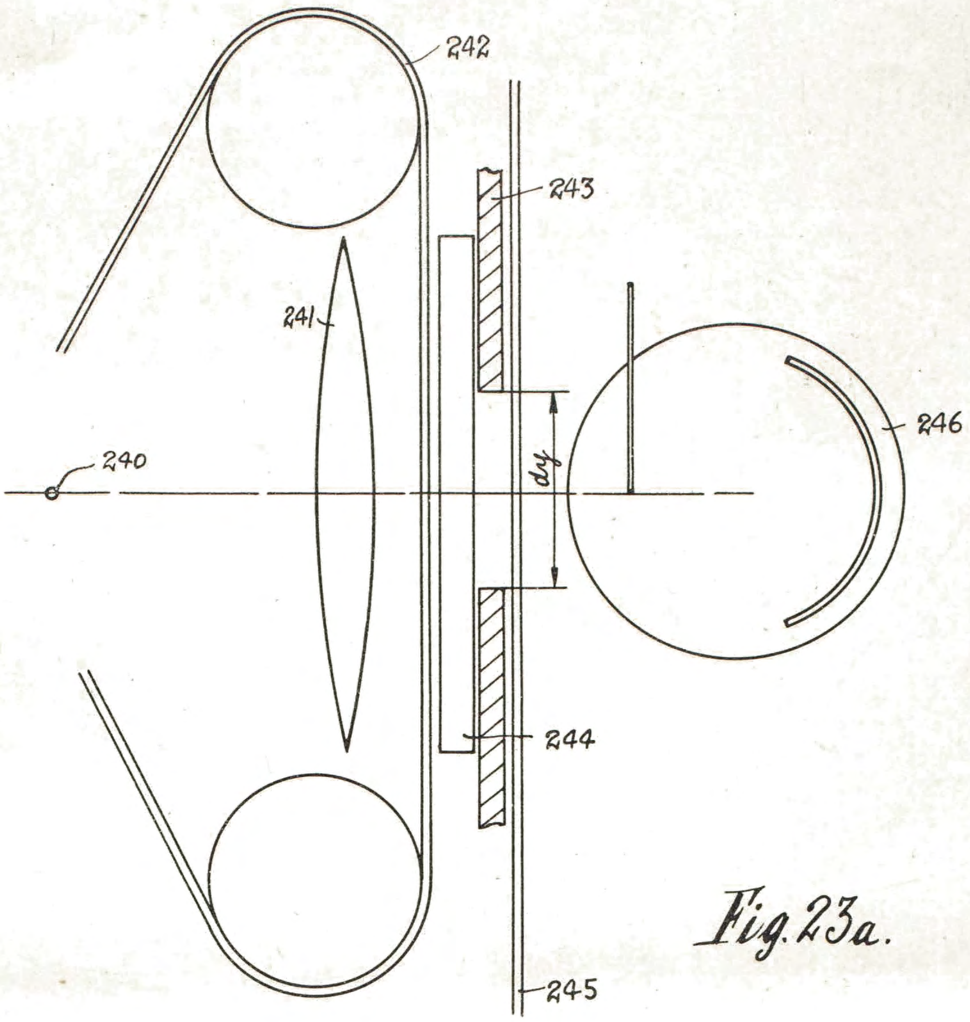


Fig. 23a.

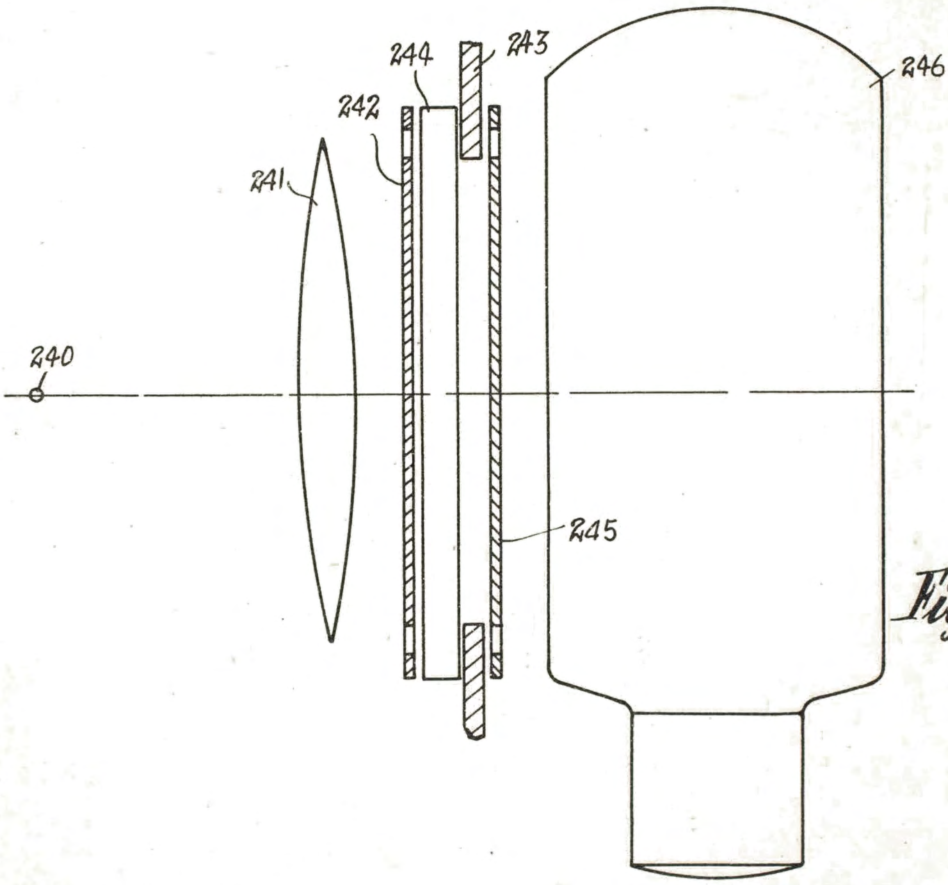


Fig. 23b.

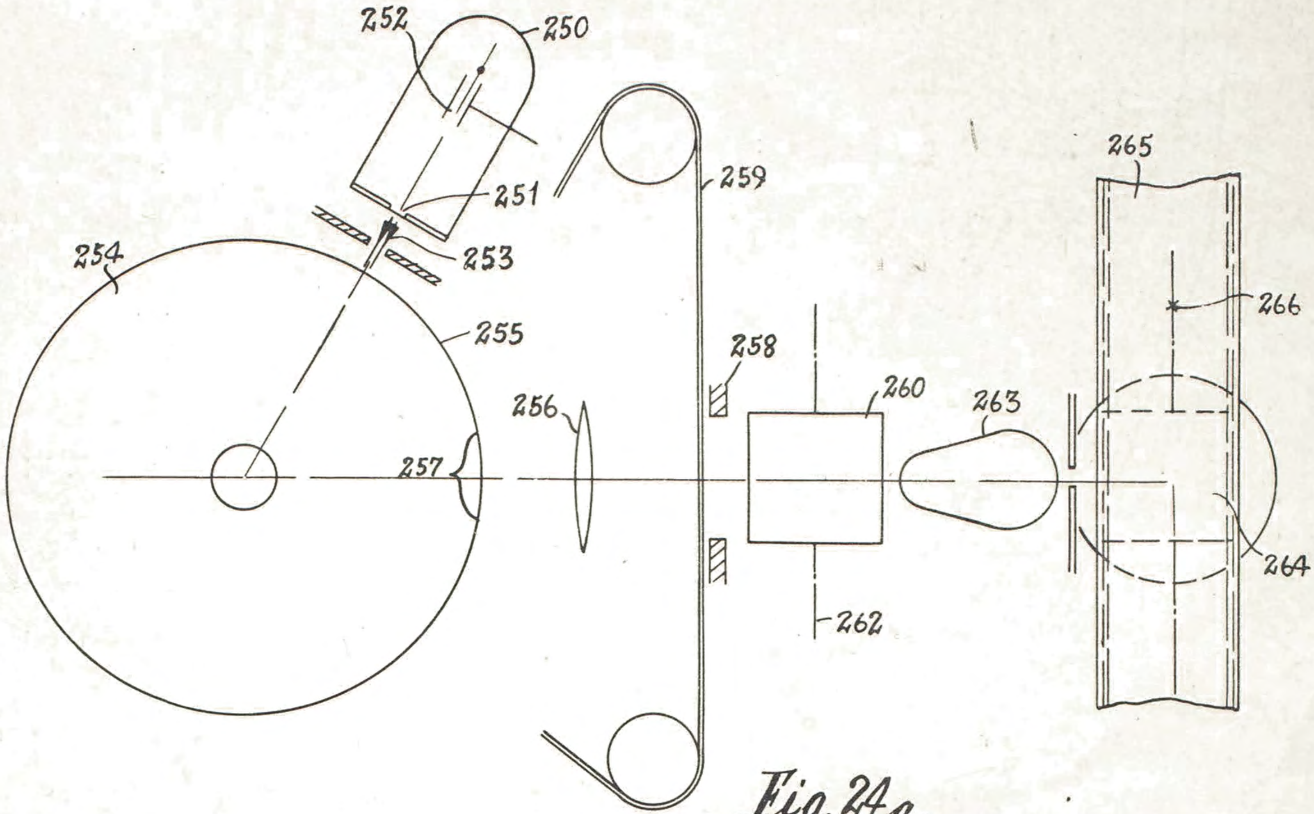


Fig. 24a.

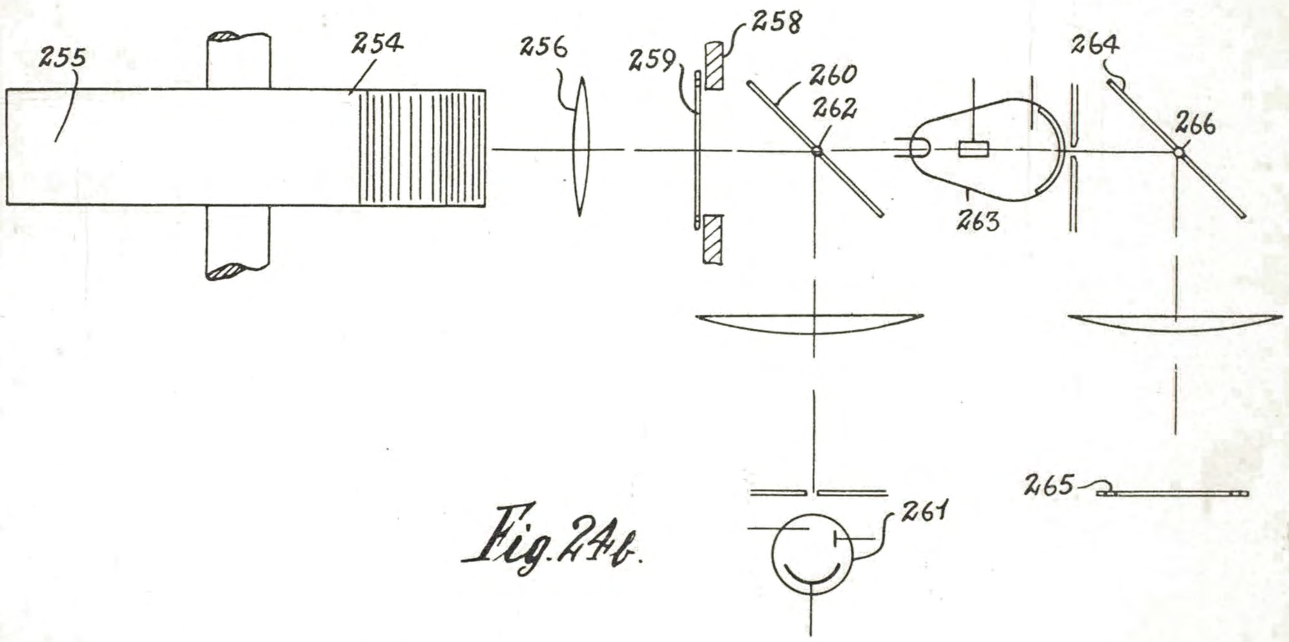


Fig. 24b.

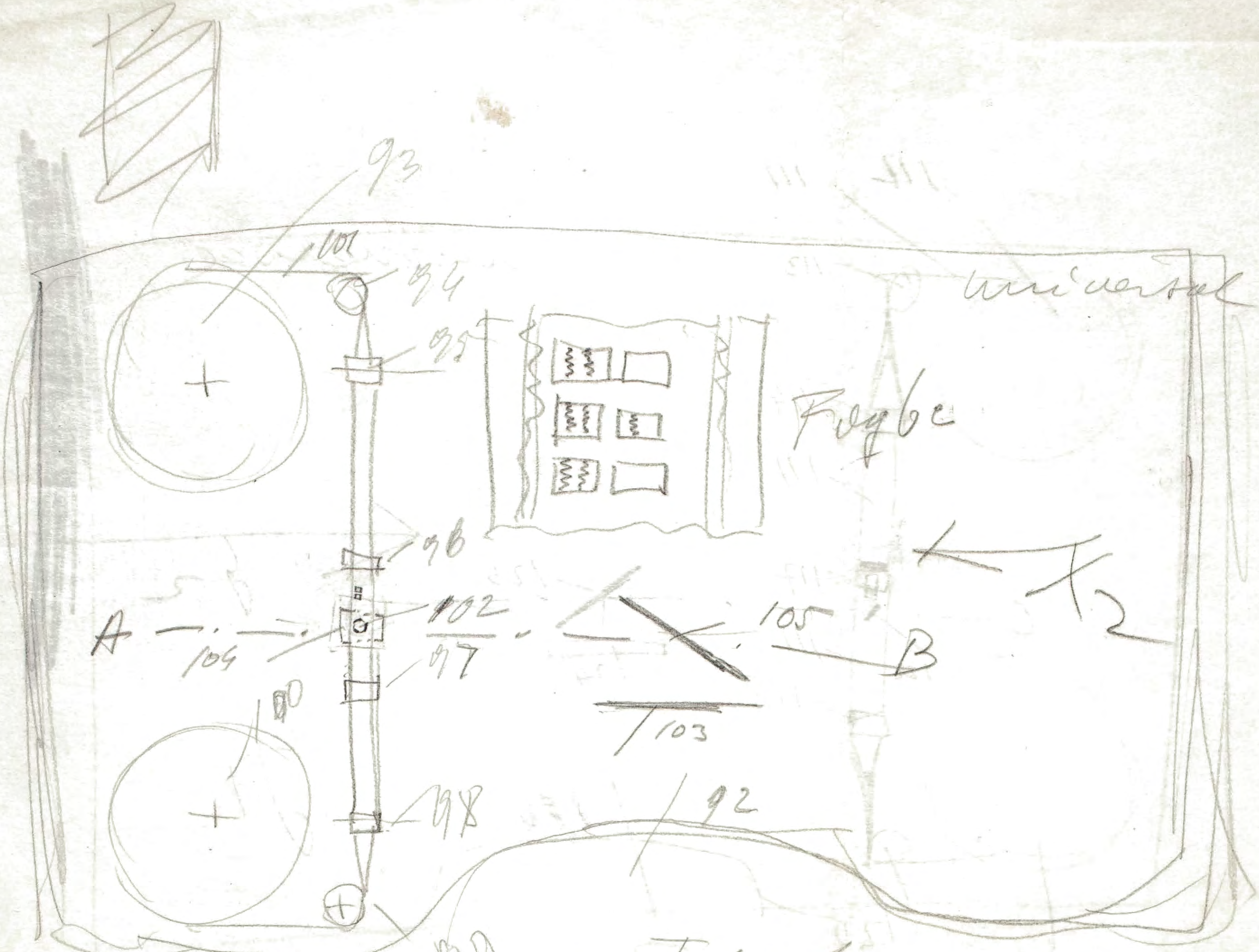
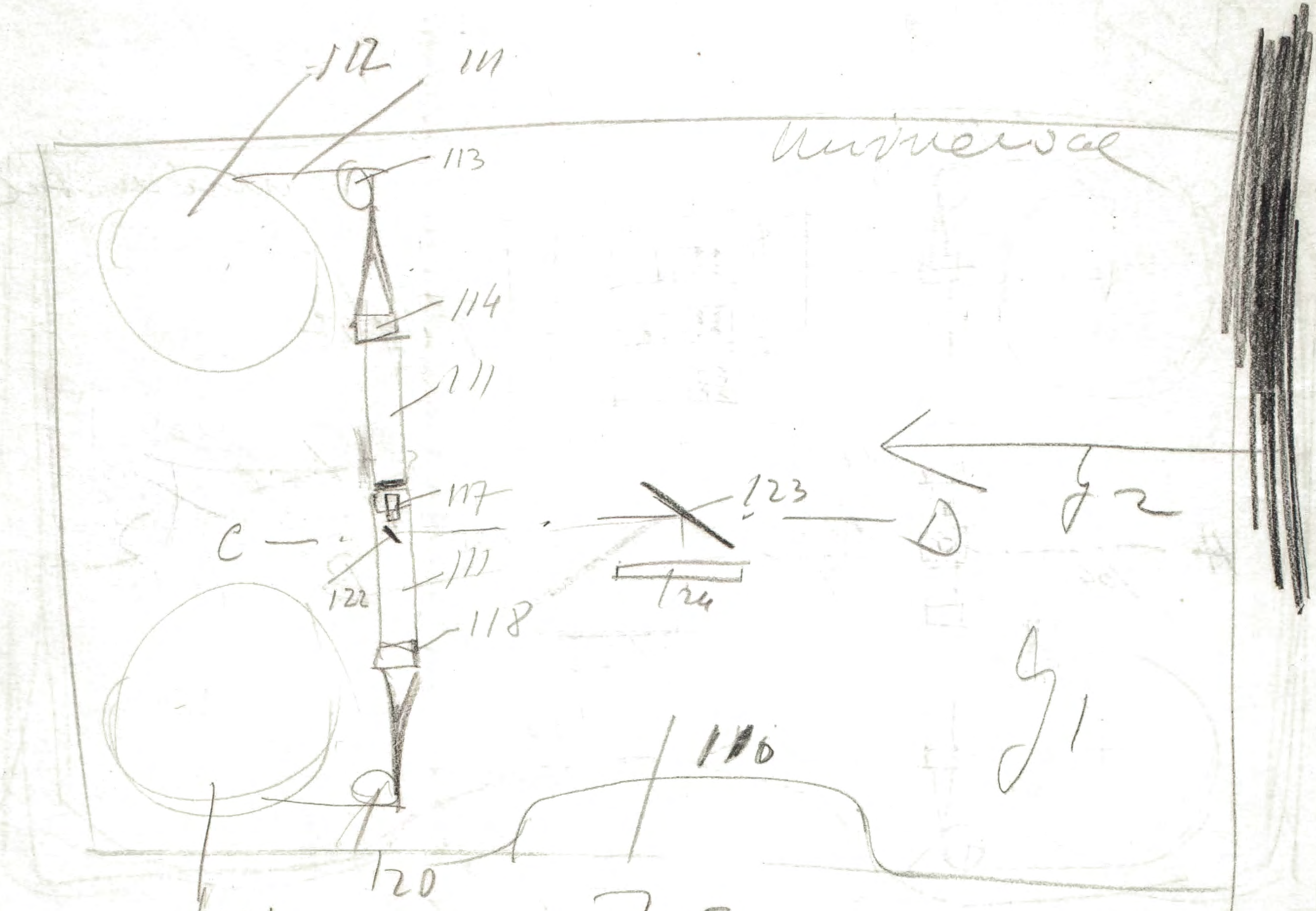


Fig X 1

Fig 6 a

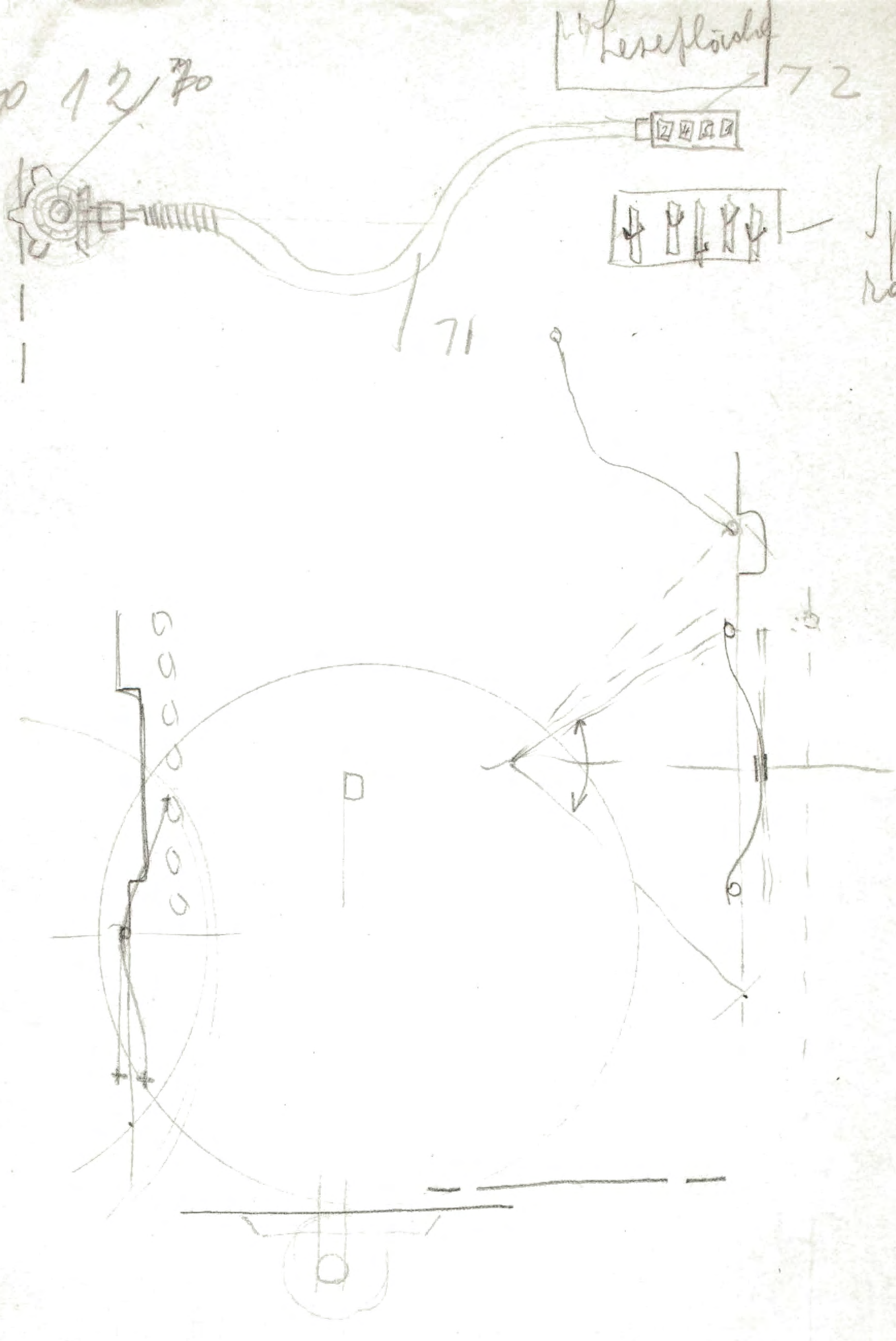


7a

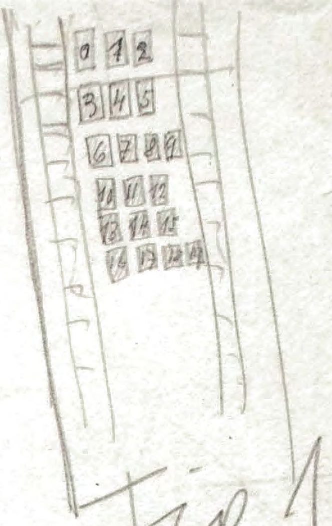
Fig 13

5

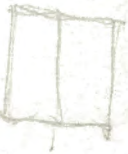
Fig 12/70

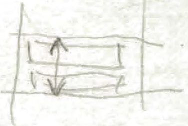


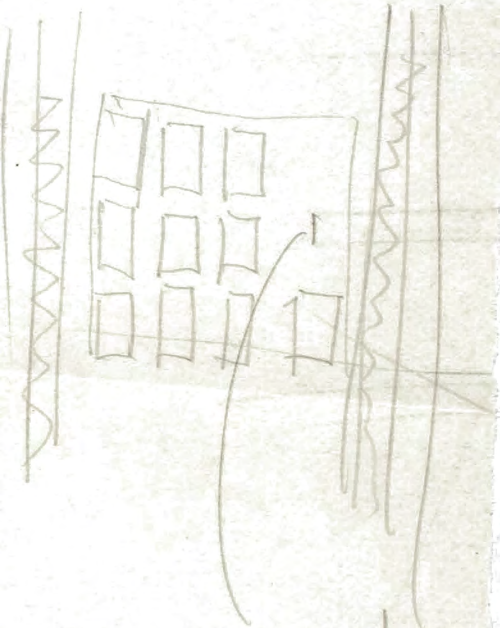
5



Tip 1







Quadrat

Lagen in Dimension (10)
durchsichtige Streifen
in schwarzem Grund

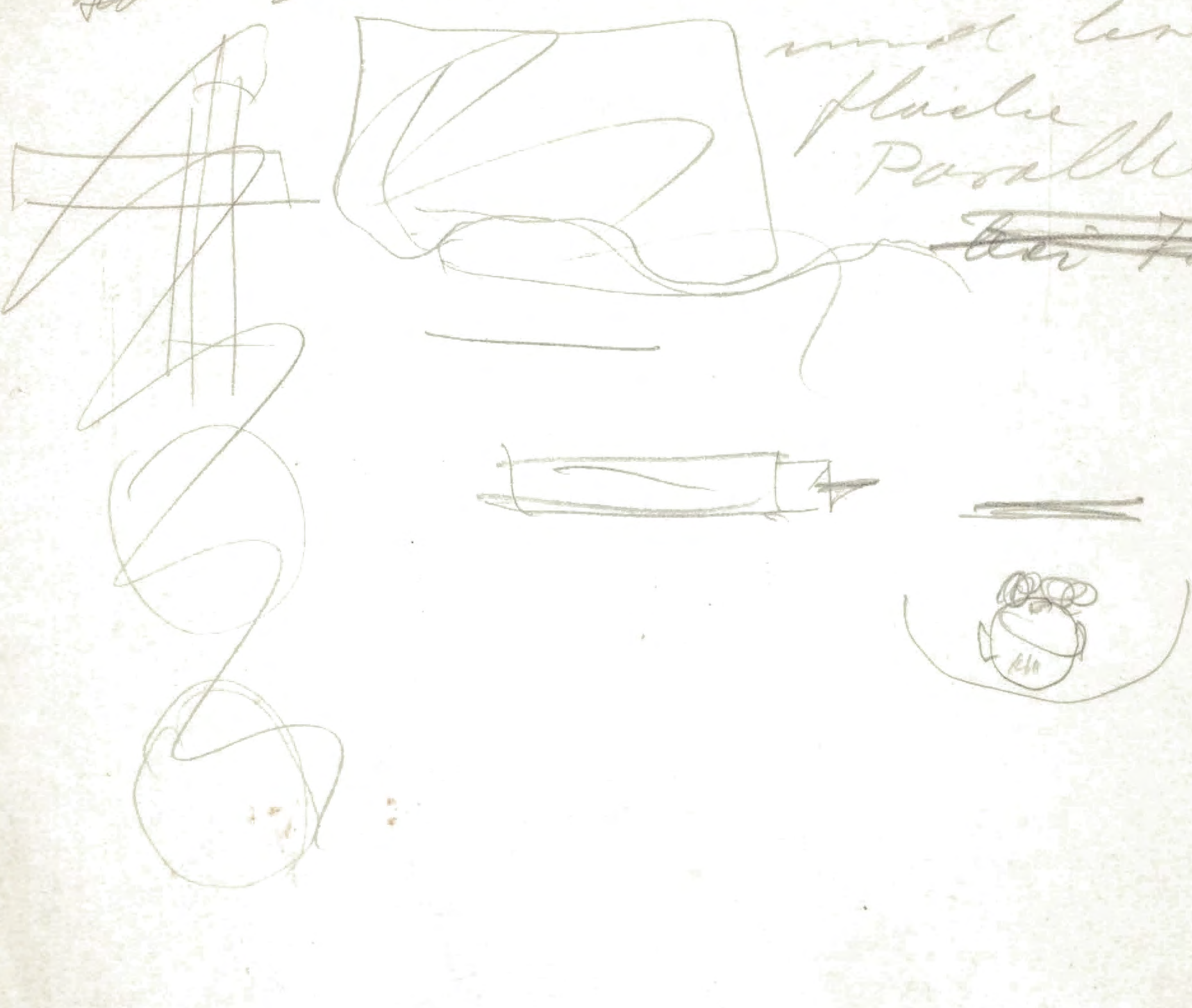
Blende

Licht

Gewisse Zahlen auslassen
z. B. 0 und 1

---

6 und 7 lassen
Scheiben um 90° ~~[illegible]~~ gegen
(gewöhnliche Lage) rot.
die Trommeln wenden
so dass ~~[illegible]~~ Trommel
und leere
Fläche
Parallele wie
~~[illegible]~~.



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6789

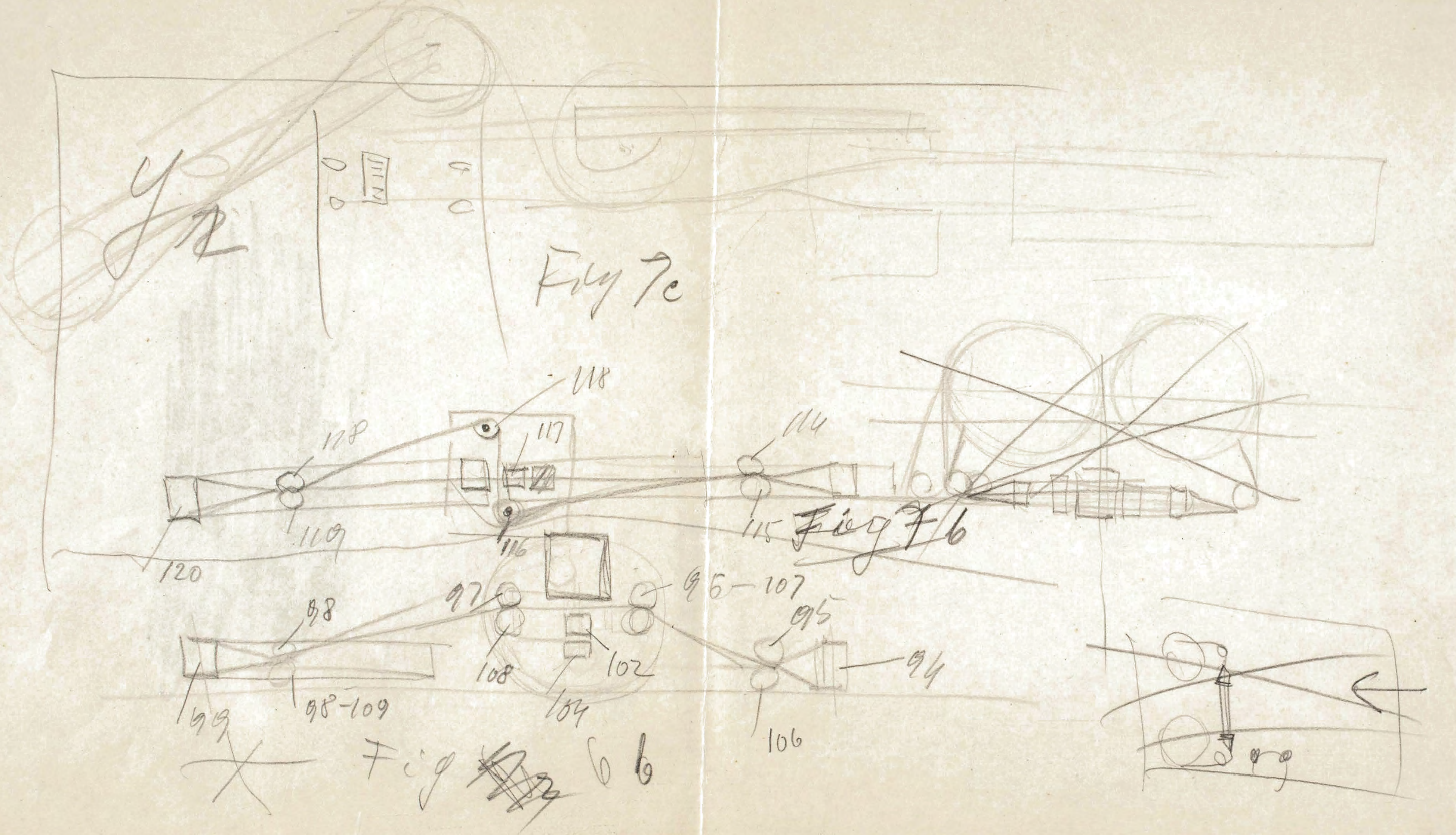
Fig 7c
118
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Fig 7b
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96–107
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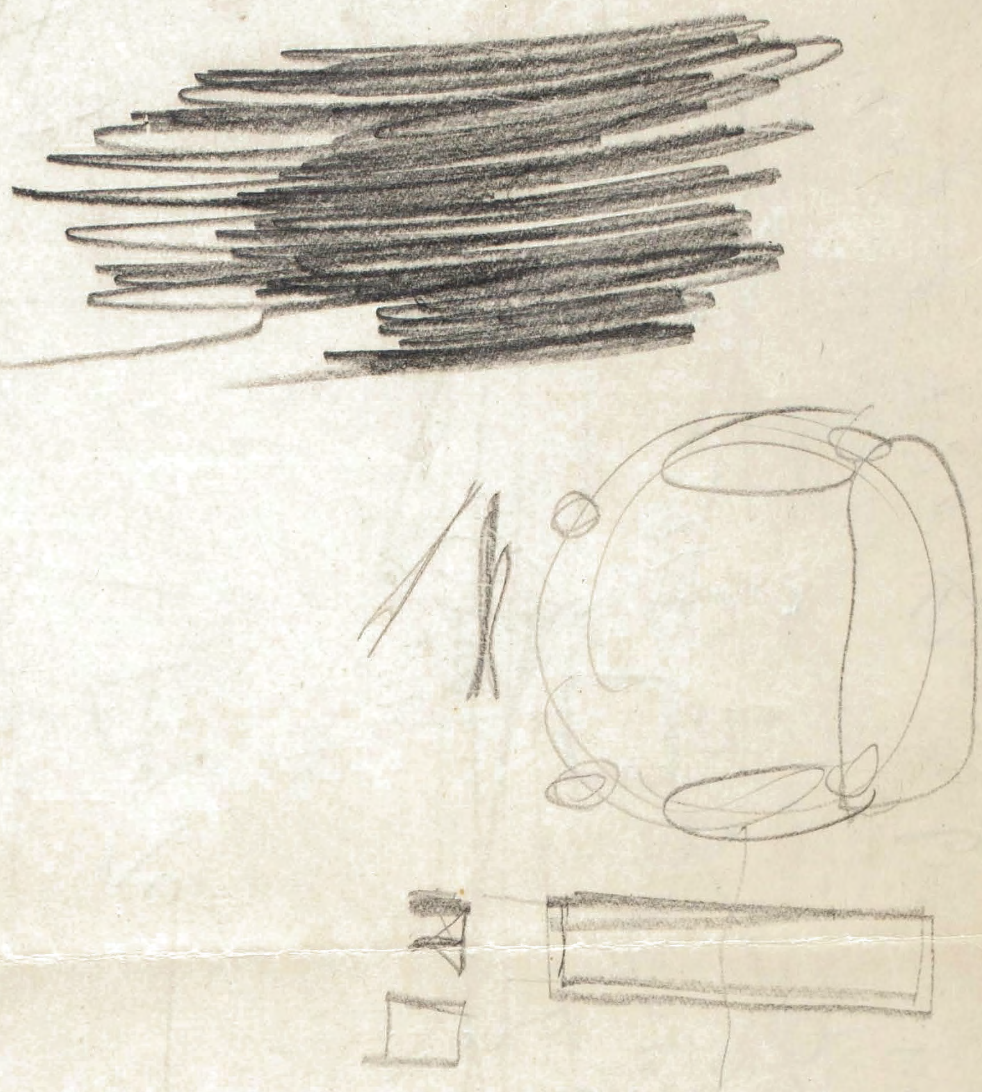
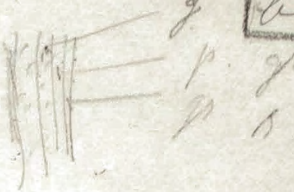
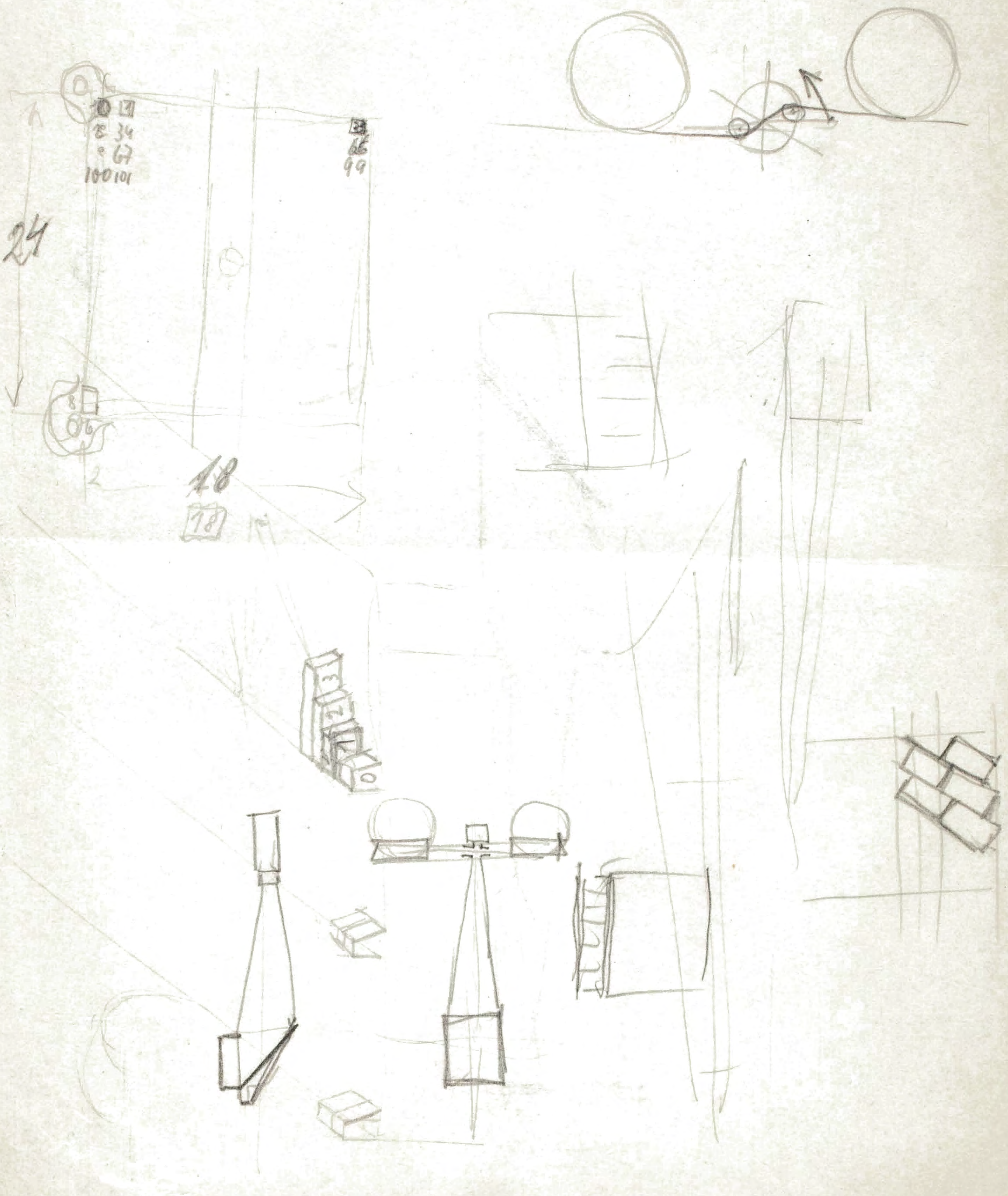
98–109
104
106
Fig 6b



b

$q = a.b$





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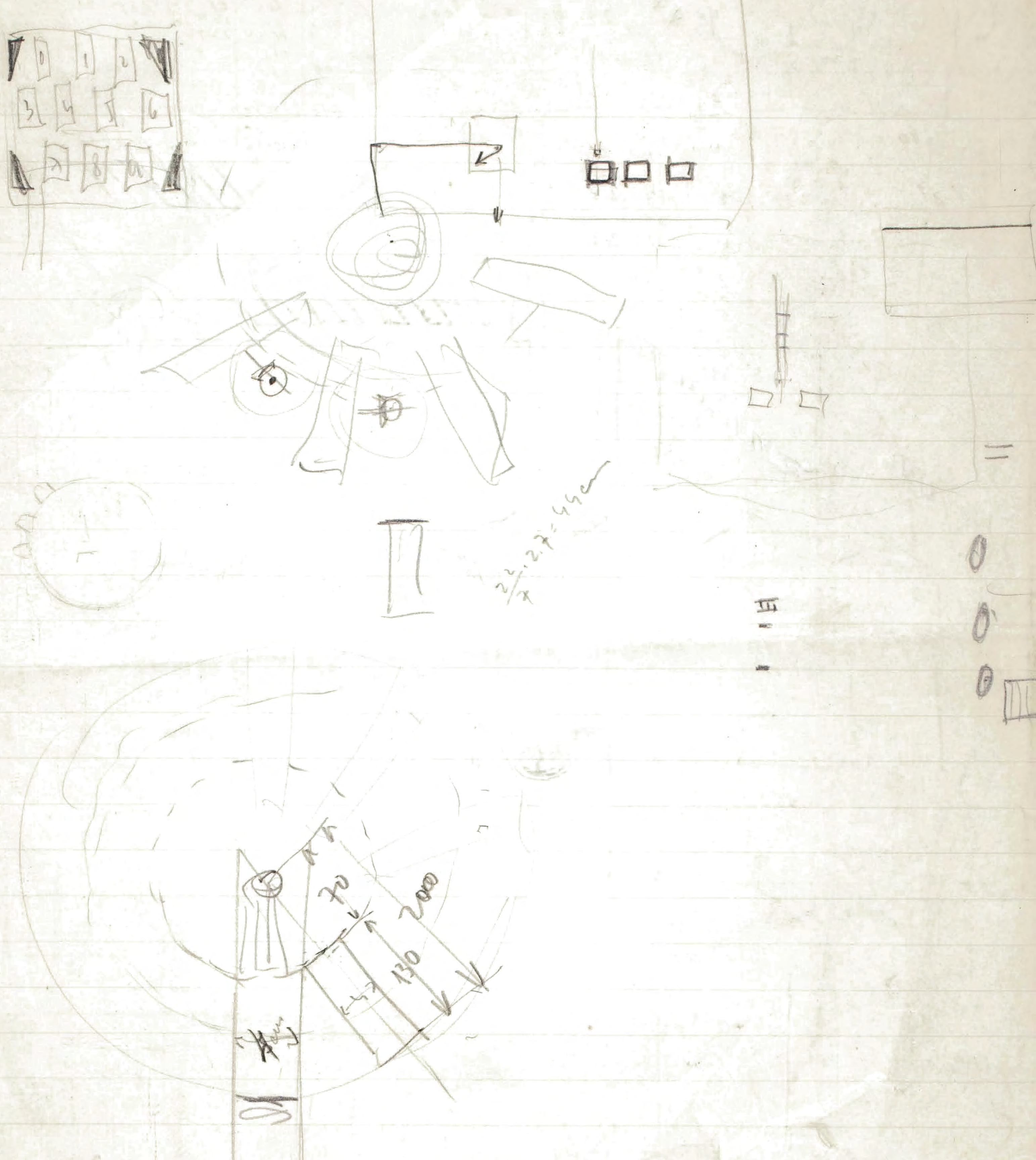
18

Fig. 1.

127



IIII $2^6 = 64$ ( )

$y = x^{\frac{k}{x}}$ a^b $z = \log y = \frac{k}{x} \log x$

$z' = \frac{k}{x} \cdot \frac{1}{x} - \log x \cdot \frac{k}{x^2} = 0$ $\frac{\log x}{x^2} = \frac{1}{x^2}$ $x = e$

1	2	3	4	5
2	4	9	16	25
3	8	27	64	125
4	16	81	256	625
5	32	243	1x	x
6	64	729		
7	128	7		
8	256			
9	512			
10	1024			

$2 \cdot 10 = 20$

○ 2^{10}

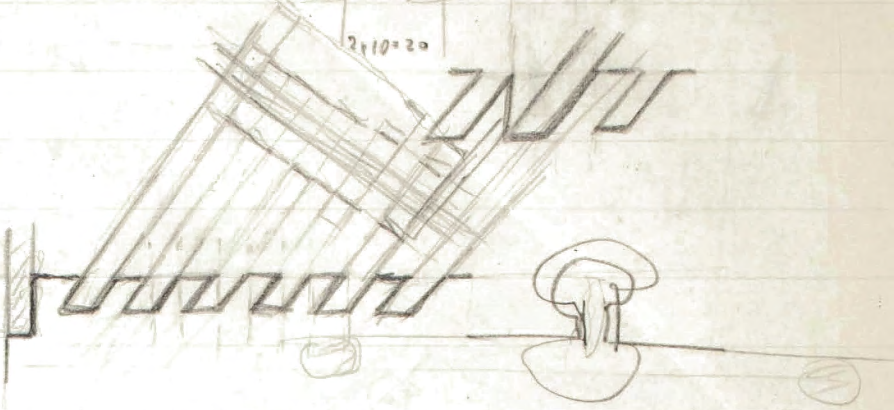
3^7

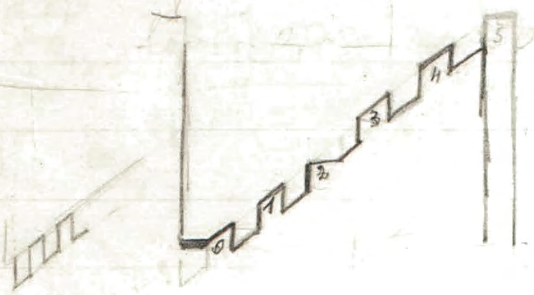
$\log 2 = 0{,}305$

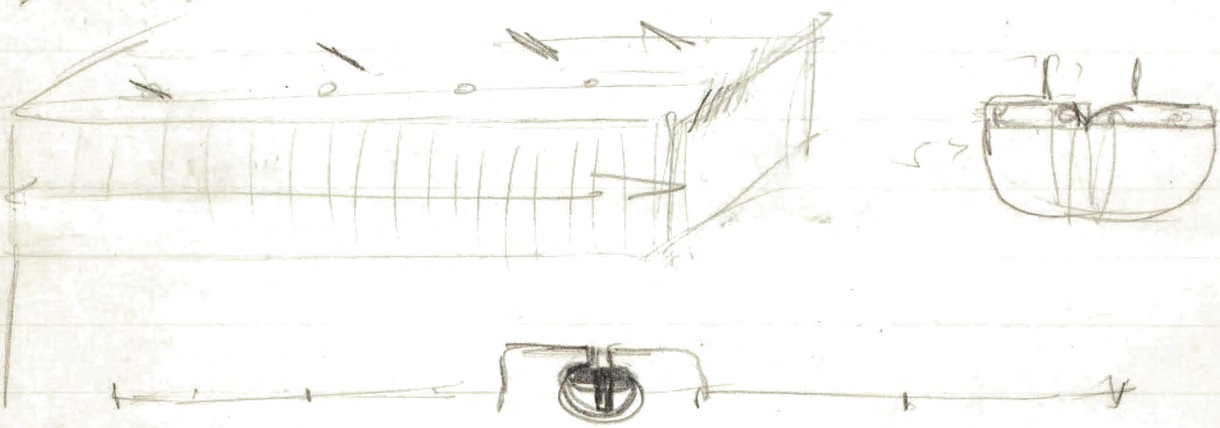
$\log 3 = 0{,}484$

~~log~~

4	
14	28
9	27
	28







$\binom{2n}{n}$ $\binom{10}{5} = \frac{10 \cdot 9 \cdot 8 \cdot 7 \cdot 6}{5 \cdot 2 \cdot 4 \cdot 3}$

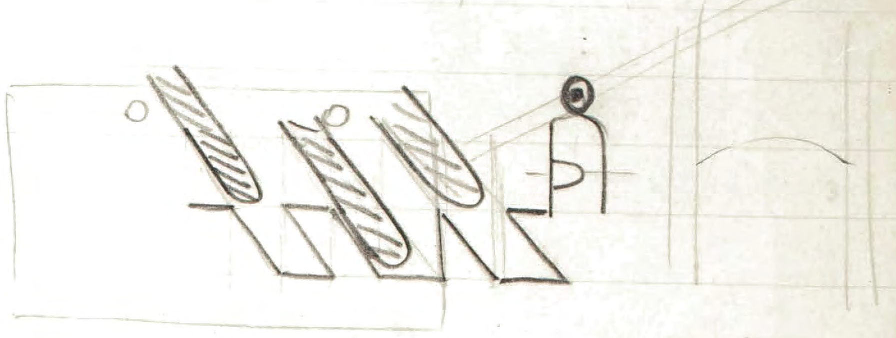
1

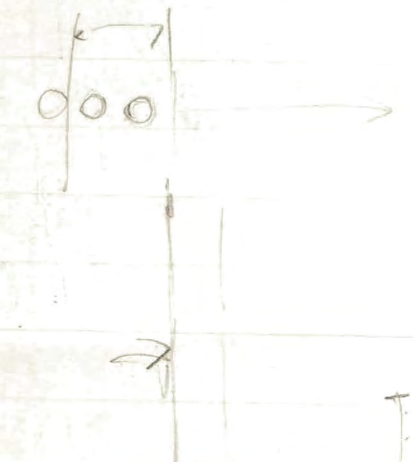
16

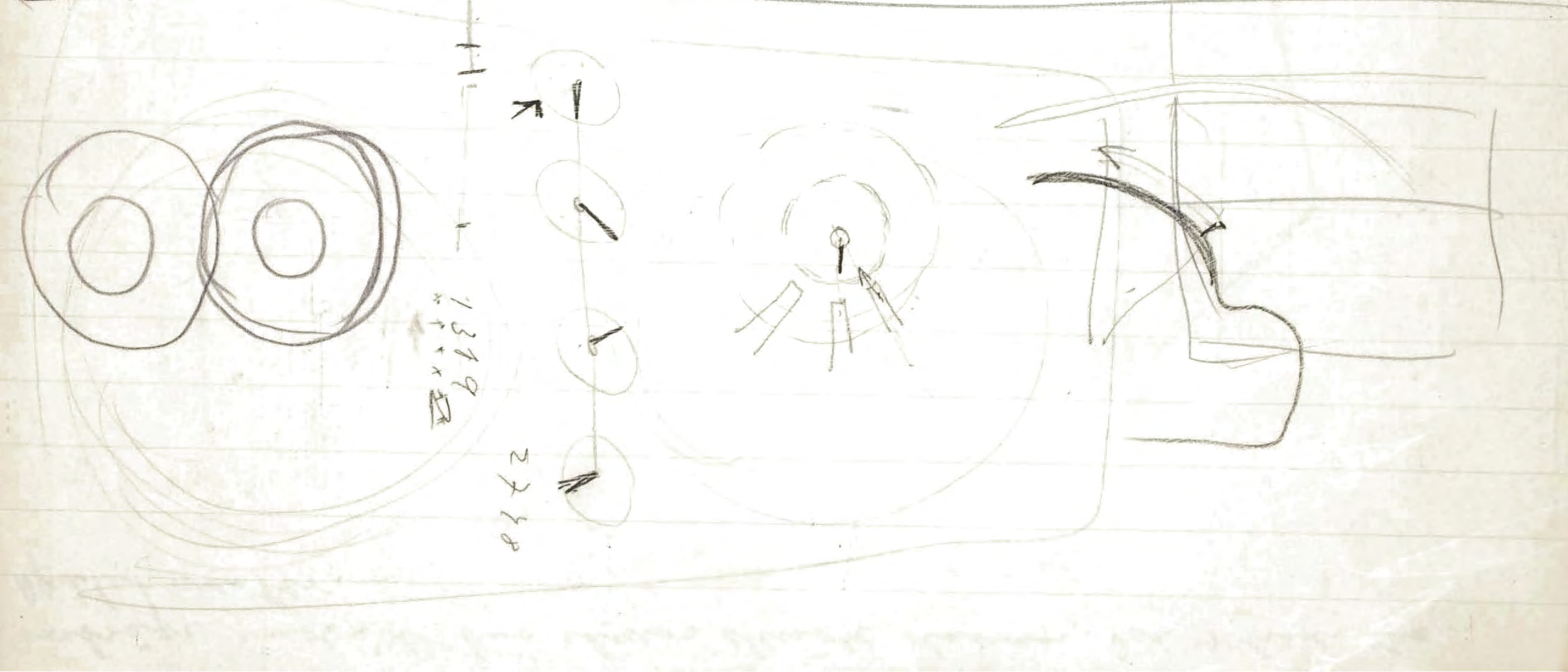
16

1^2	2^6	3^4	4^3	
	64	81	64	10,000

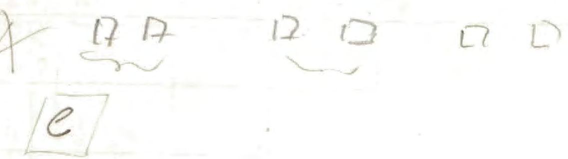
dreiersystem
oder $\binom{2n}{n}$



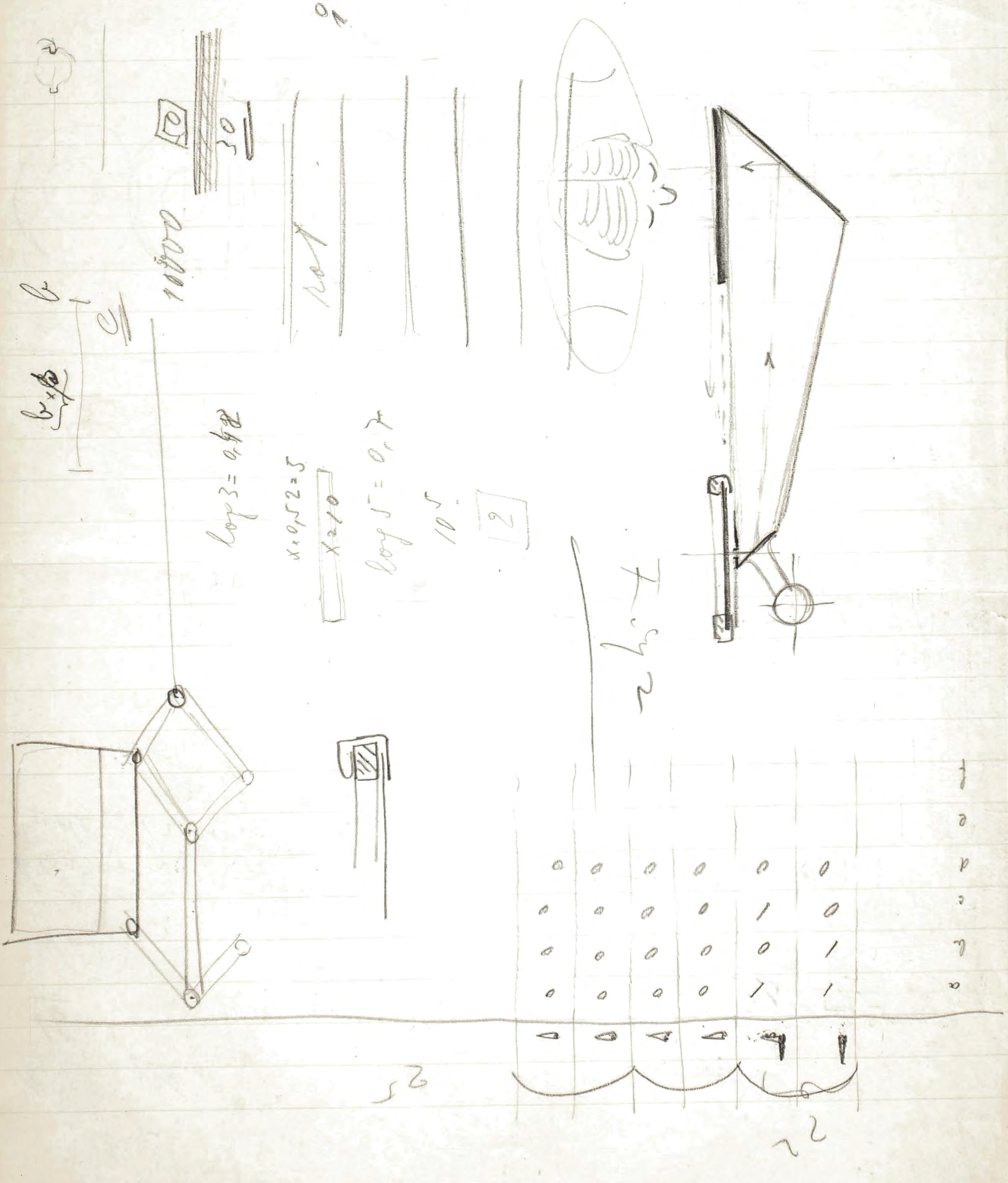


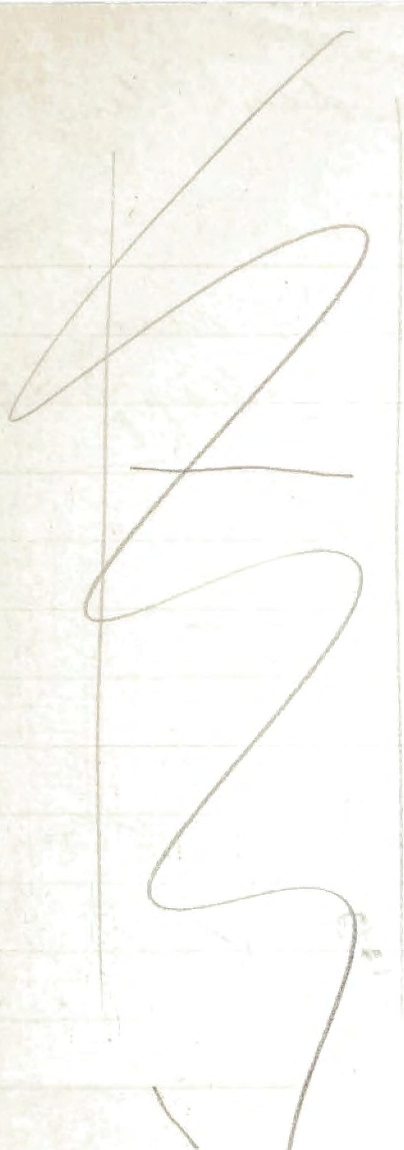


1319



vorträge und ich bin etwas müde davon. Ich schreibe
Später weiter.—



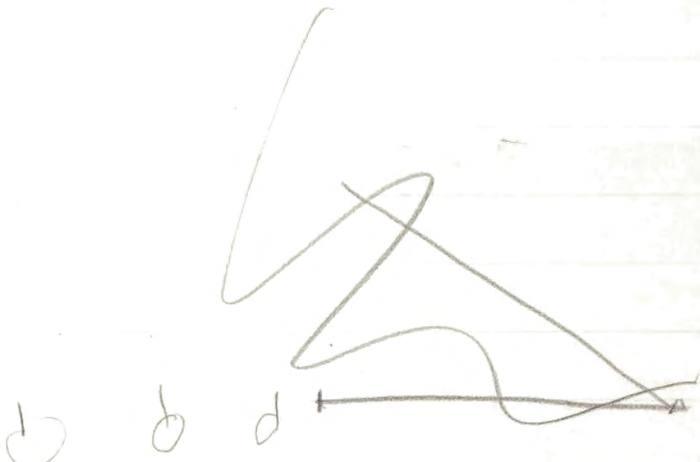


Krankheit

wohl, schwer [illegible]

$$\int \psi H \psi(r_{ik})\, d\tau = Rh$$

$$\left| \frac{\partial x_i}{\partial r_{ik}} \right|$$



$\mathrm{Det}(r_{ik}^2)$

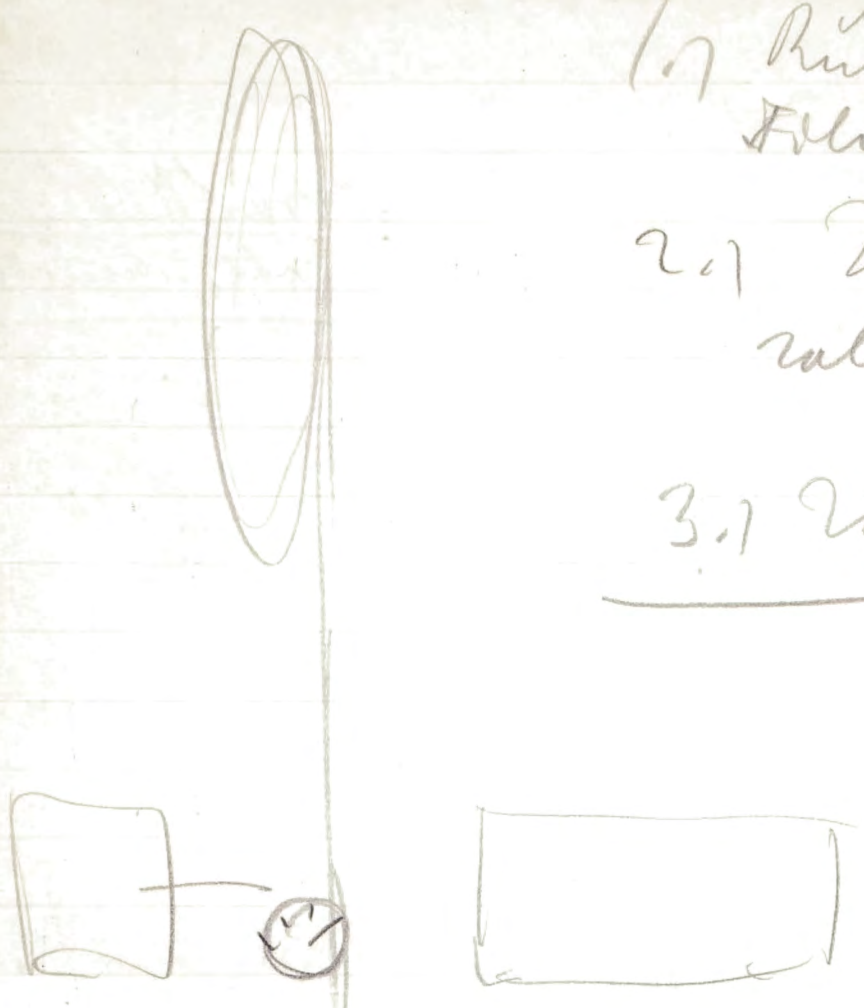
$$\mathrm{Det}\left| r_{ik}^2 \right| = 194\ V^2$$

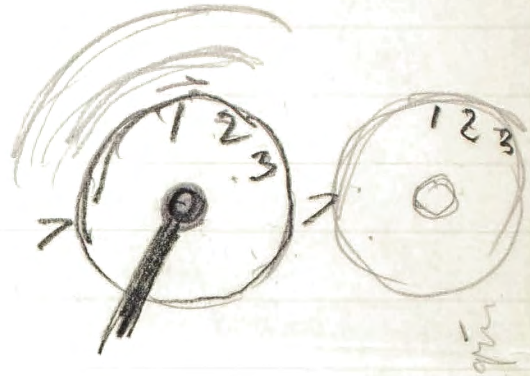
$> 2 \cdot 10^{10}$ e Volt

1.) Ruhelage des Polen
Polenmitte

2.) Zählwerk mit
Zahlenrad gekoppelt

3.) Zählwerk

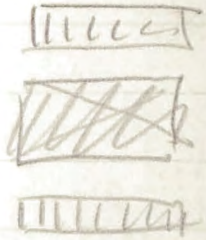




Unesö

1.)

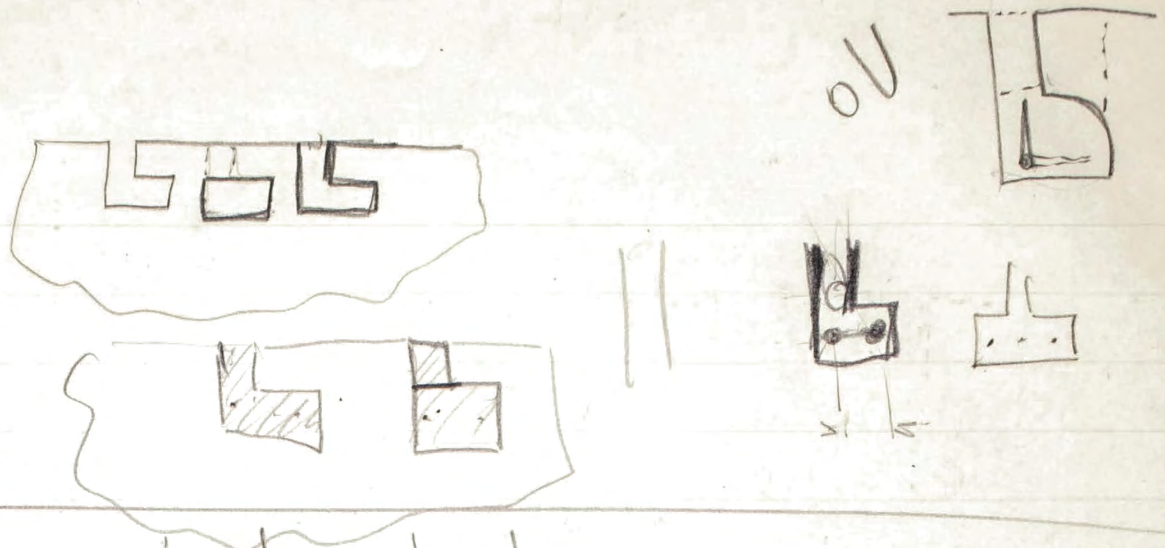
2a) rot gelb grün



2b) Nicht Dekadisch!

10

2^{10}

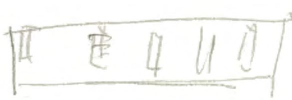


!! o o o

Amerikanische Masch.

Flachmodell

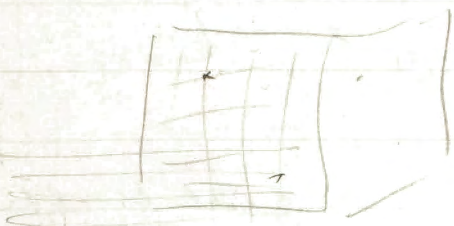
Keresö

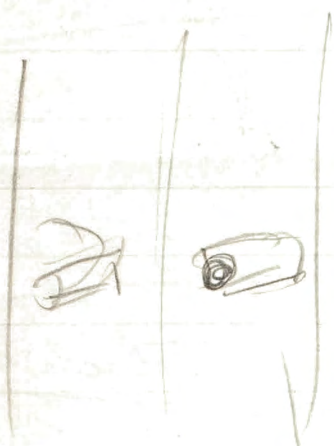


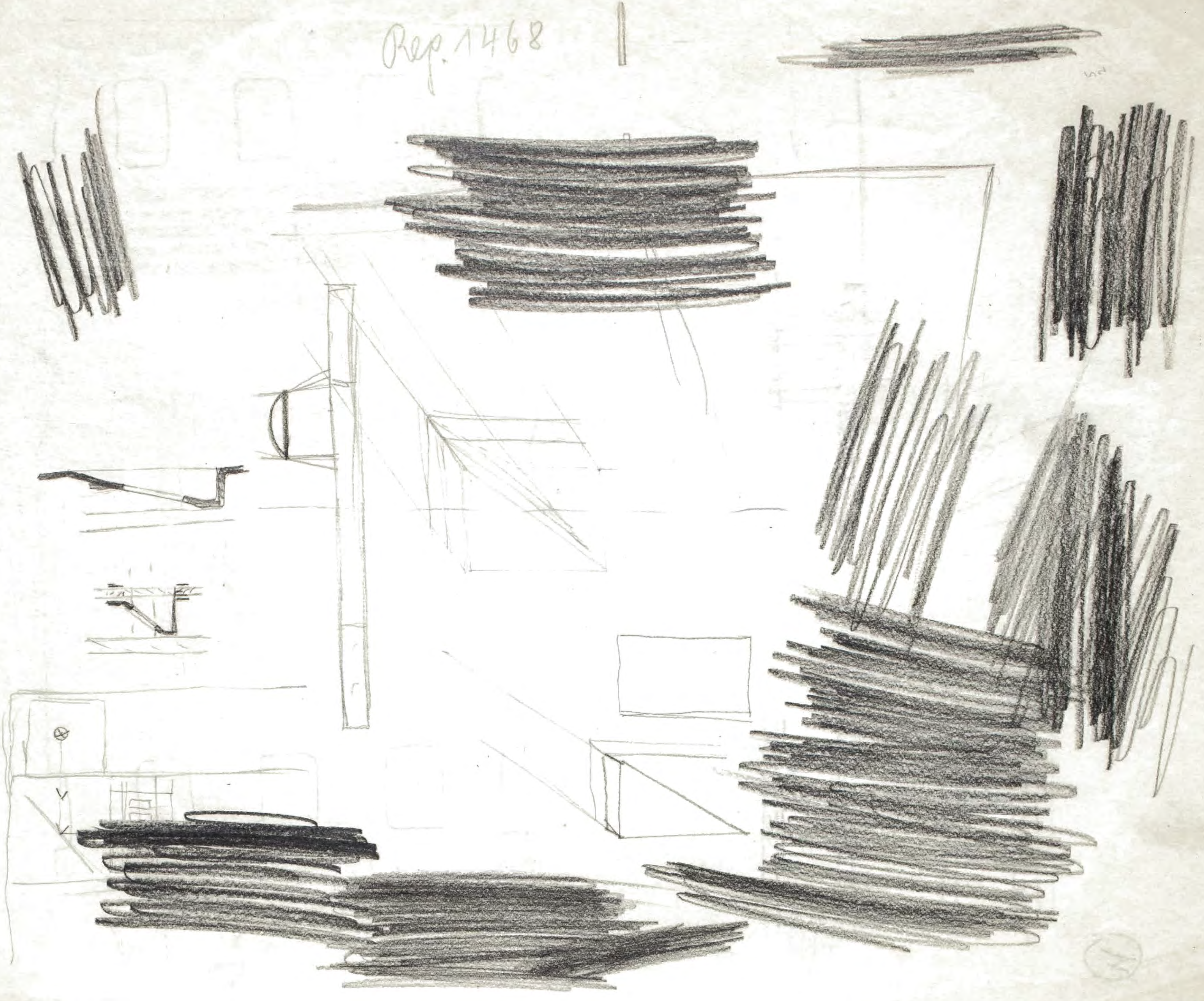
Keresö mit Blendrad

~~[illegible]~~ Zählwerk
Subtraktionszählwerk
Ruhestand in Folumwalke
Backen

~~[illegible]~~ Spiegel







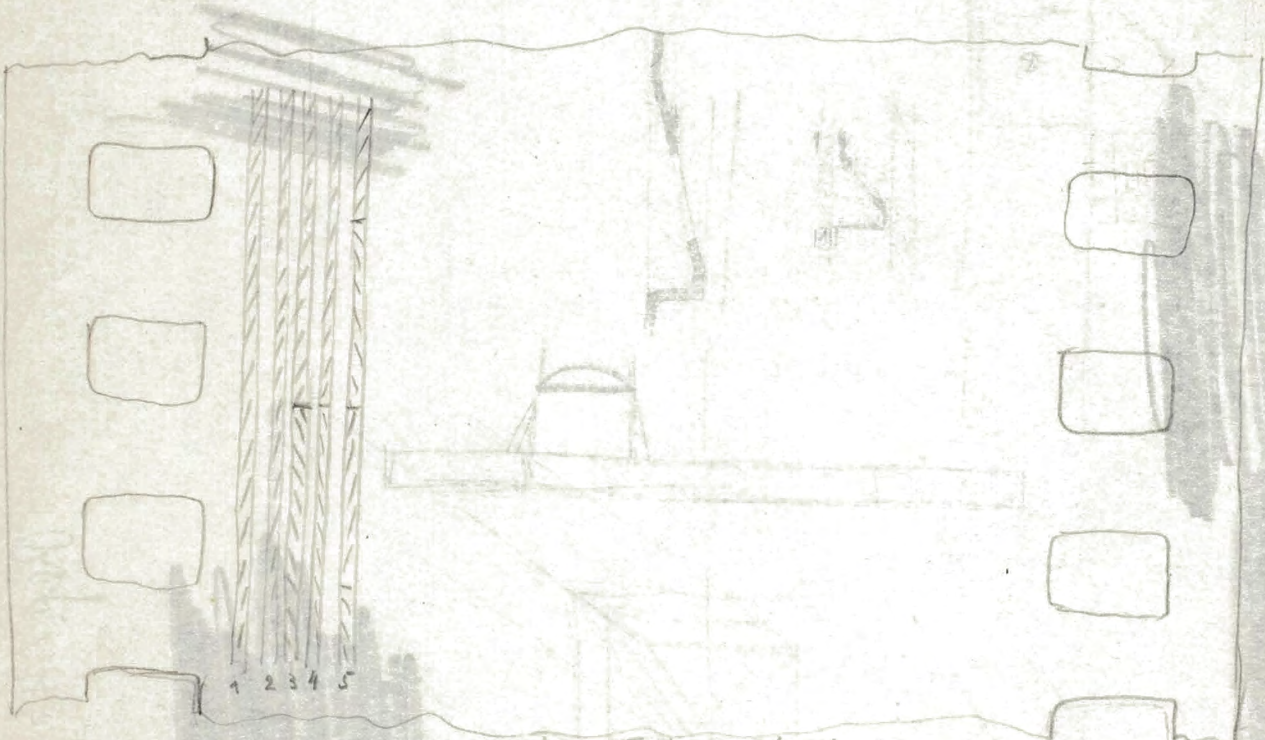


Fig 14

Fig 15

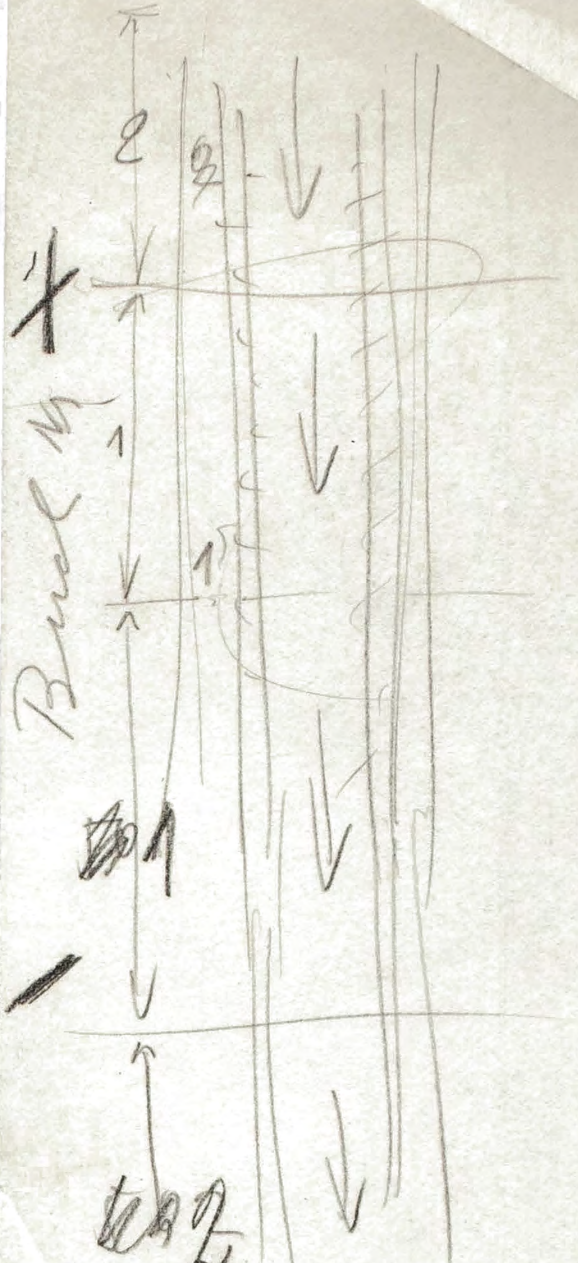
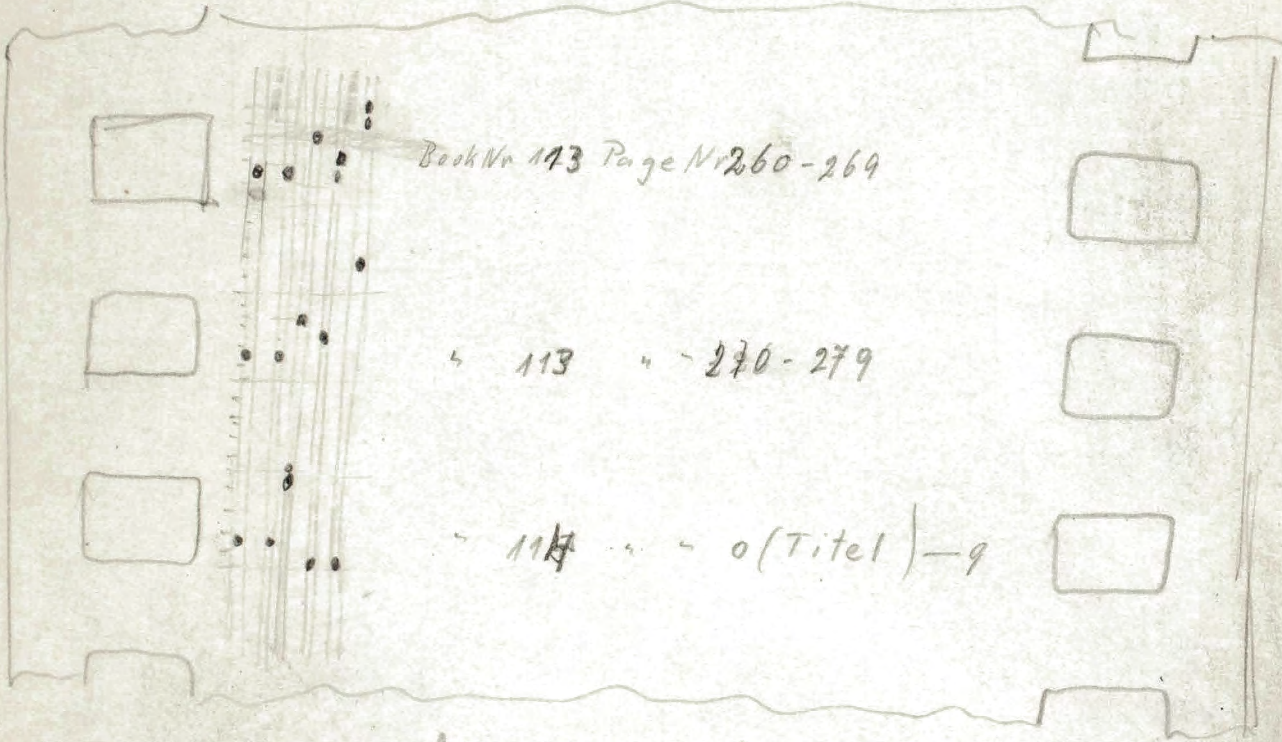


Fig 21


Book Nr 113 Page Nr 260-269
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„ 114 „ „ 0 (Titel) - 9

Fig 16

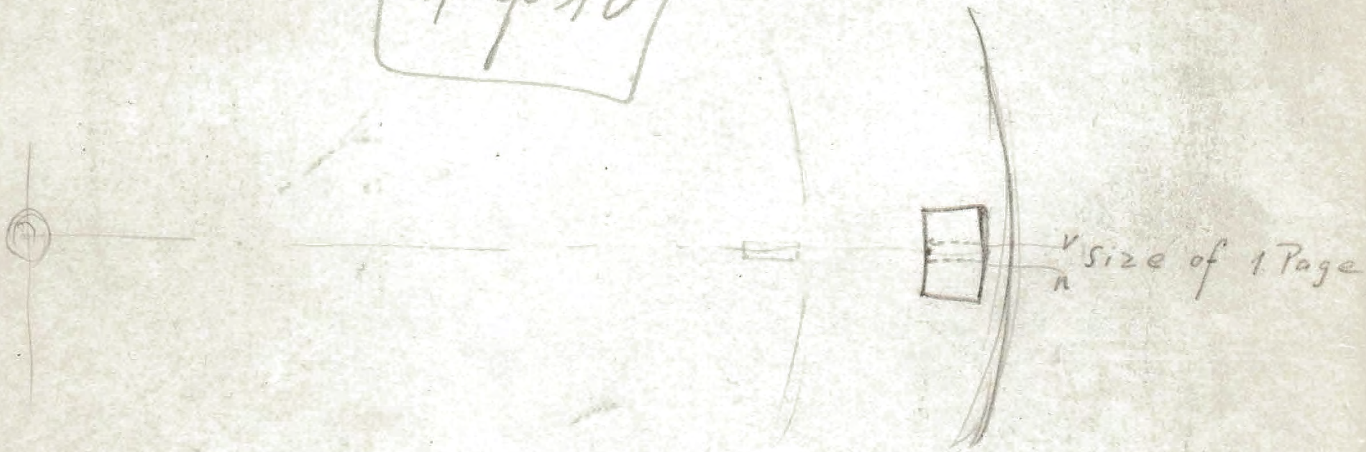
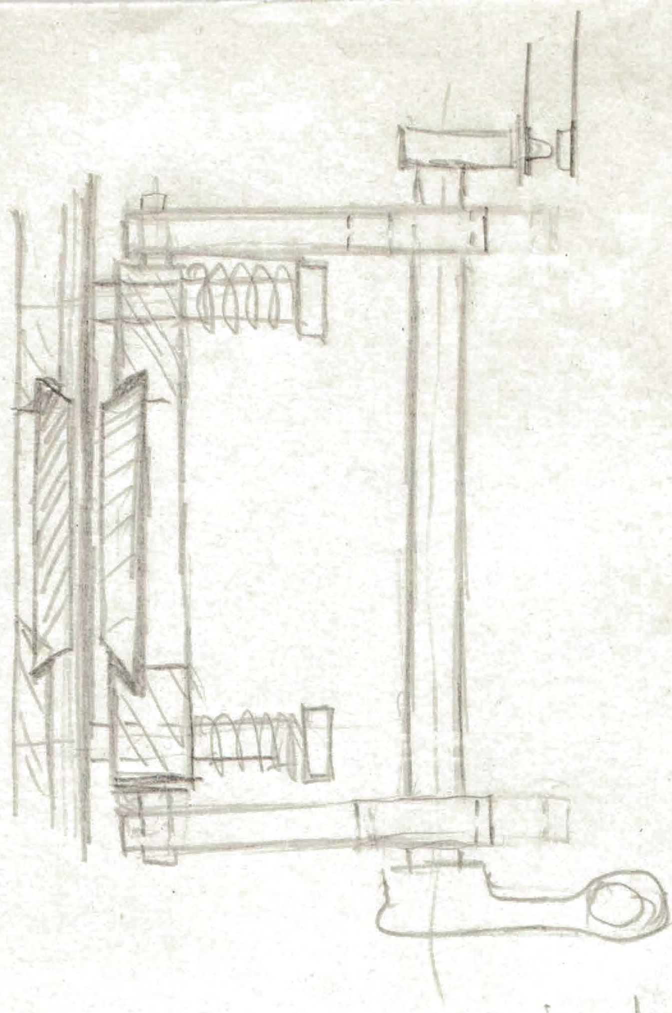

Size of 1 Page

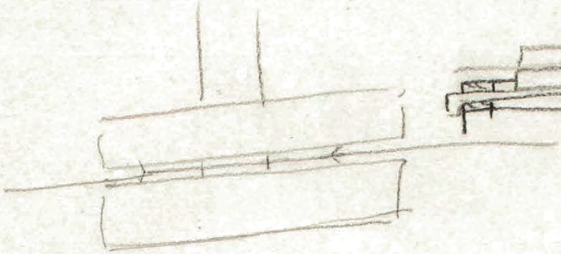
Fig 17

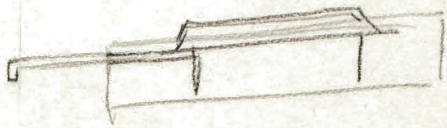


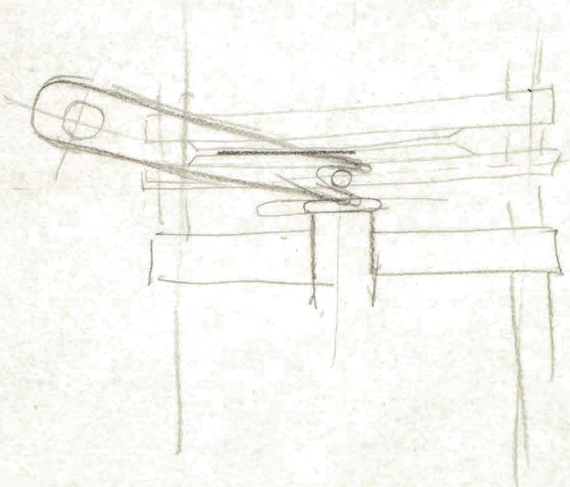
2 Lösungen:
1x Presse mit Film bewegt
1x " fest mit Objektiv
gemeinsame Auslösung

2. { 1x

(1)







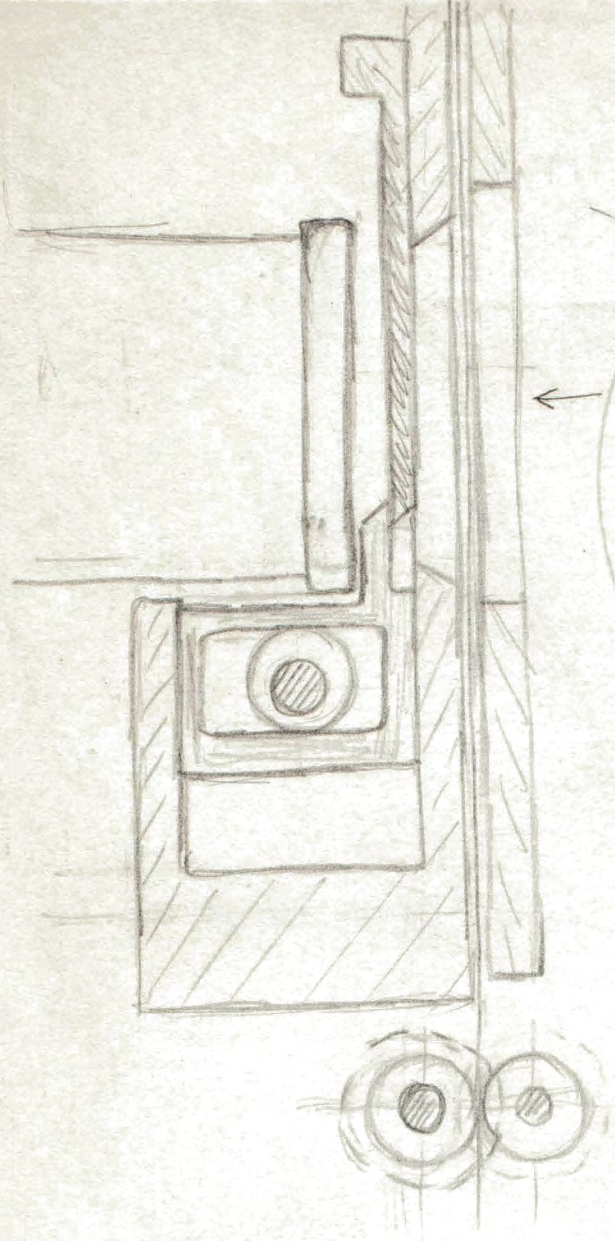
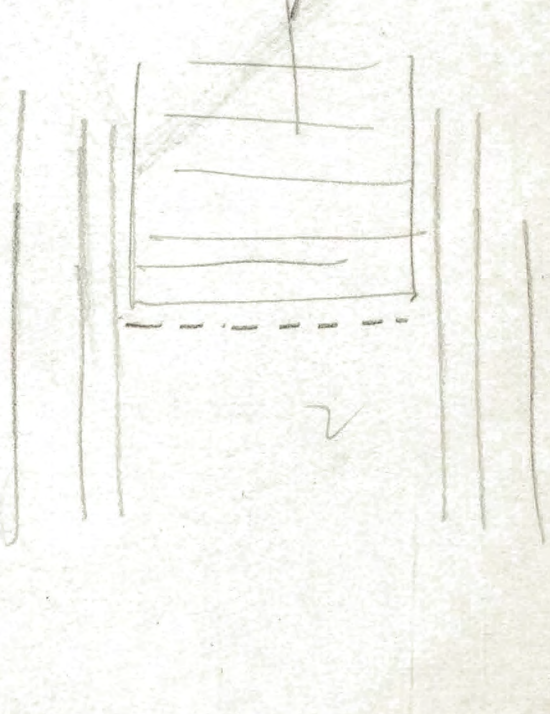
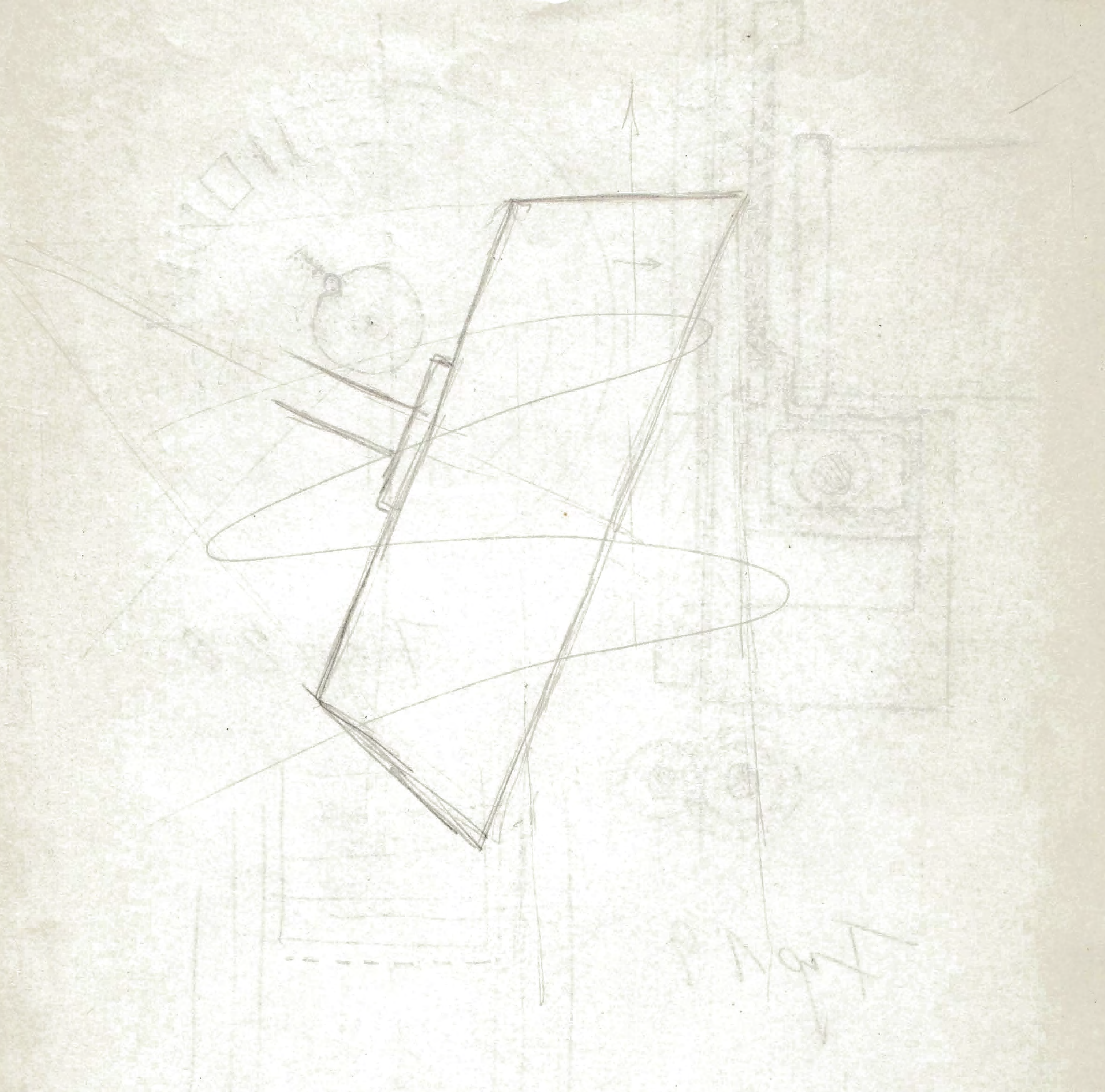


Fig 19

Fig 20





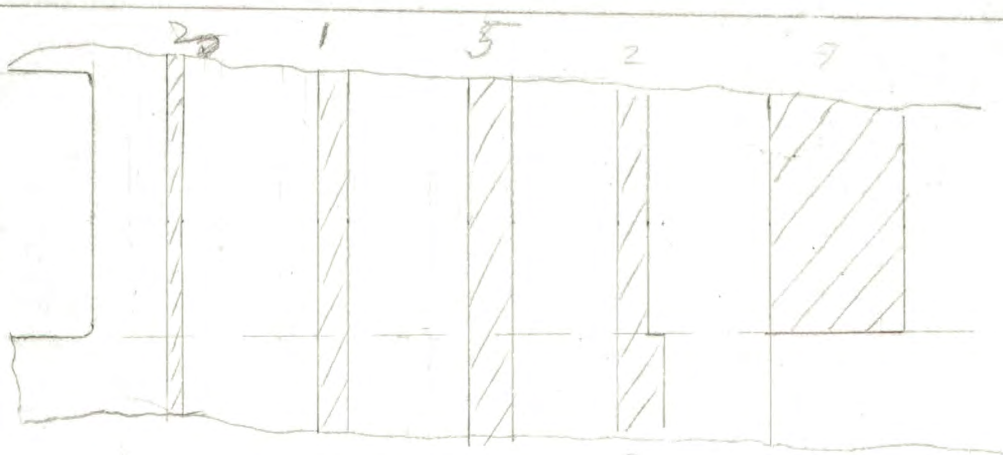
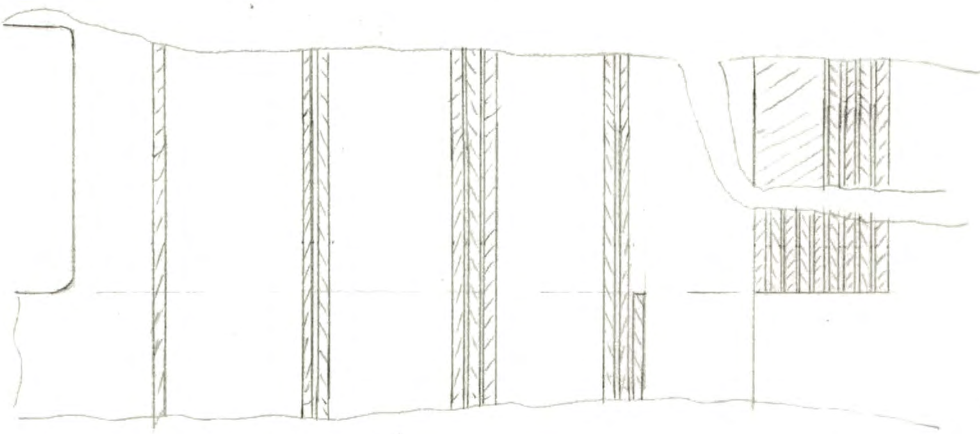
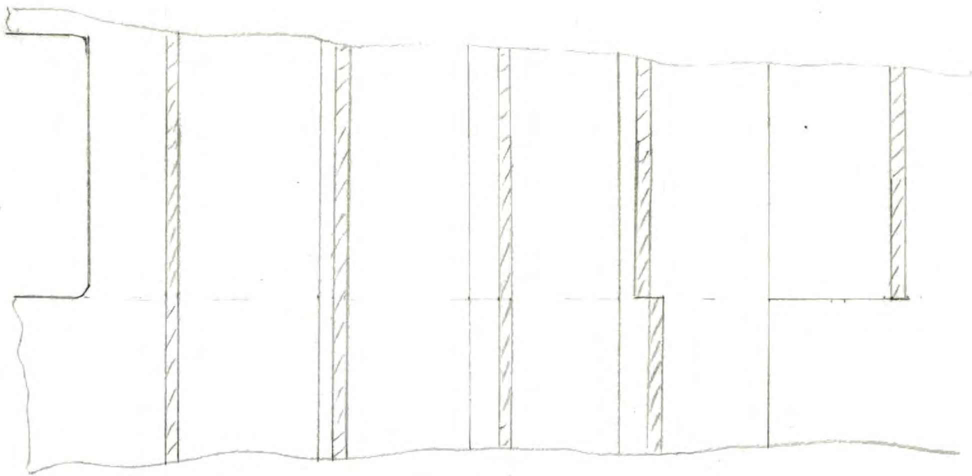


Fig 8

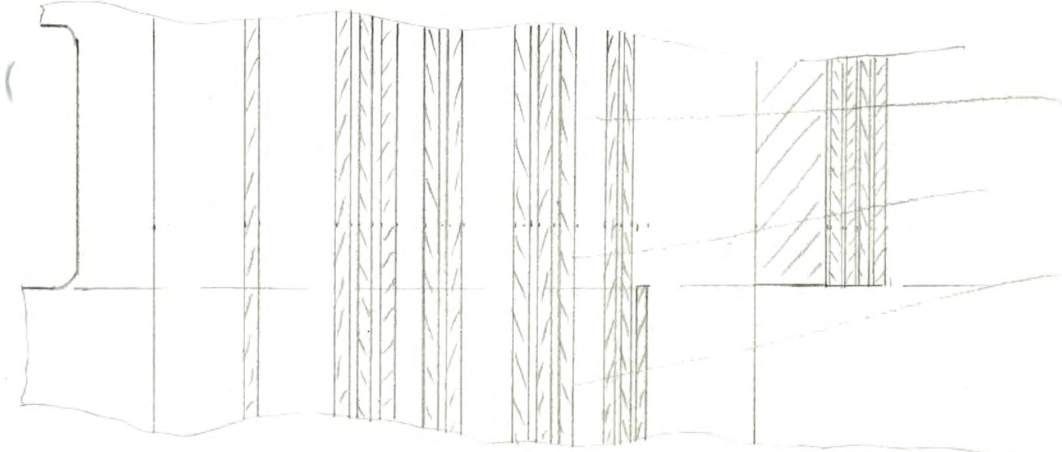


9a

9



10



11.

$123_{(10)} = 1323_{(4)}$

(1)

Undated

Reprod. of Sound

Unkorn.

Reproduction of Sound.

The invention concerns a method for registering sound, for instance speech or music by photographic methods on 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 of the film y which is in front of slit 4, but also a quickly moving film 3 in the sound generator which is continuously revolting in itself passing in front of slit 4. An optical lense 2 makes the light of the light source 1 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 of speech the modulator film 5 carries a record of the individual piece of speech or music which is to be reproduced.

In figure 2 you see two pieces of the film strips which move past each other drawn below one another. The upper film strip 5 is the modulator film. The section y which is in front of the slit 4 corresponds to a period of time of 1/10 to 1/30th of a second, that is to say that in 1/10 to 1/30th of a second the section y passes the slit 4, and after that time a new section of the modulator film will be in front of the slit 4. This period of time (which may be 1/10th to 1/30th of a second) will be called the time basis of the record. If one goes within the section y from left to right across the film 5 one passes 11 sections and the transparency of each section (the amount of light each section will allow to pass) determine the composition of the sound which is produced at the moment when the section y 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 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 y. Such a curve is shown in figure 3. It gives the frequency spectrum of the sound at a definite moment within the basic period of time. X need not be a direct measure of the frequency, but the frequency is a function of x ( ) the form of which can be chosen to suit certain requirements. The film 3 in figure 2 is also divided into 11 sections x (x , x , x , ... x). Within each of these sections x the transparency varies along the film as a sinus function of y (transparency =). is a constant i.e. its value does not vary with y but it varies from one section x to another being a function of x. Of course varies also from one section x to another being a function of x.

If the film 5 would remain fixed the section y being in front of the slit 4 and the film 3 would be moved past the slit 4 with a velocity v one would hear a sound composed of 11 frequencies i.e. the frequencies each of them with an intensity determined by the transparency of film 5 at the corresponding sections . The individual values of the transparency for the definite sections x can be seen from the curve in figure 5. If film 5 would 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 1/30th of a second another section 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 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 x has a transparent section surrounded by two non-transparent sections. The amount of light transmitted by section 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 non-"transparent" sections. The breadth of the "transparent" section is constant along the film (it 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 varies along the film.

If the slit 4 has a width of 1/10 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 need 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 1/40 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. 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 Δx is created by a transparent section within each section x, the width of the said transparent section varying with y.

~~Of course a sound generator film of the first mentioned type can be used also in combination with a modulator film of the type shown in figure 5.~~

It has been mentioned that the number of the sections 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 $\Delta\nu$ should be about $\Delta\nu = \frac{\nu}{100}$; i.e. 1% of the frequency we shall have to use about ~~$N = \frac{5000}{100} \times z$ frequencies, where z is given by $e^z = \frac{5000}{100}$; i.e. $N \cong 200$,~~ $N \cong 400$

Figure 7 shows the usual arrangement of transforming the variations in the intensity of the light (that enters ~~falling on~~ 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 connected to the cathode 71 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 positive pole 79 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 1, 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 image 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 surface and throws a faint image of the film 103 in front of 104 through the dark filter 109 on the photocell 110. The use of 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 x has, though a very small, yet finite value in the absence of the frequencies in the sound which ought to be recorded. If the second photocell were not present weak light of all frequencies would reach photocell 106 in all circumstances and would produce disturbing sounds. If one uses a 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 x of the sound modulating film 105 has its minimum value (which signifies the absence of the corresponding sound that has to be recorded).

Figure 9 shows how the photocells 106 and 110 are used. 115 is a high voltage battery, the positive pole 116 of which is connected to the anodex 117 of the cell 110 and the anode 118 of the cell 106. The cathode119 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 battery,/132 the 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 cathode 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 ~~kxm~~ cathodes 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 can 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 x which are isolated from each other by blackened strips 51, 52, 53 .... . Within each section 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 1 of the film (i.e. the transparency varies with y along section 1 according to); another sinus function of a slightly different wave length is photographed on section 2. Section 1 and section 2 are over-lapping as indicated in figure 10. In the same way a third sinus function is photographed on section 3, the wave length being again shifted a little against the wave length of section 2. Section 3 is over-lapping sections 1 and 2 in the manner indicated in figure 10. If light is admitted by the modulator film at a definite very narrow section 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 centre of gravity of which will be determined by x. The breadth of the band depends on the breadth/D of the sections 1, 2, 3 ...., on the shift d of these sections with respect to each other, and on the shift of frequency from ~~xx~~ one section to another. The breadth of the band produced by light transmitted at a definite spot x will approximately be

If we wish to reproduce music it is important that the mean frequency generated by light transmitted at a definite spot x should be proportional to x ( ). If this condition is fulfilled ( ) a small shift of the modulator film with respect to the sound generator film in the direction ~~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 ~~shows~~ 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 of the film which corresponds to a certain length of time say 1/10 to 1/40th of a second which we will call the basic length of time of the sound generator film of this type. The line 153 indicates the middle of the section y. The transparency of the film in the section 1 is given by a function y being the y co-ordinate of the middle of section y.

This function is shown in figure 11a. The transparency of the film in the section 2 (which is shifted in respect of section 1 by d, and is over lapping section 1) is given by a function

being ~~shifted~~ slightly different from . This function is shown in figure 11b. The same applies to section 3 and so on.

The next section y between 152 and 154 is made exactly alike the section y between 151 and 152; again all the functions copied within this section y have their maxima in the middle of the section 155. The same holds for ~~the~~ every following section y.

The boundaries of the sections y 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 non-transparent and transparent lines running at 45° 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

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 i.e. . 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 film on which ~~the sound~~ a piece of music or speech is recorded in one of the two usual ways. The 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 of the sound generator film 160 and of the film 161. The length Y corresponds on the record 161 to a certain length of time the basic length of time of the operation of transcription ( ). While a certain section of the record 161 is in front of the window 164, the film record 161 being at rest, the film 160 which will be called the "analyser" is kept moving. The light transmitted by the section Y of both films is collected by the lense 165 and thrown on the photocell 166.as As shown in figure 15b the window 164 admits only light across a small section dx 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 dx of the analyser representing a given mean frequency in front of the window and ~~moving with the velocity~~ 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 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 on the film record 161. If the alternating current 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 dx of the film 169 the transparency of the section dx will be determined by the intensity of the oscillation 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 164 ~~together with~~ and at the same time different spots x of the film 169 are brought in front of the slit 168. At each section dx at the spot x of the film 169 the intensity of the corresponding oscillation on the film record 161 ~~is registered~~ 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. ~~Then as next step~~ During this motion the film 161 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 instance 1/10 of the basic length of time of the transcription operation (for instance 161 is ~~shifted~~ moved along by 1/10 of Y). 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 which is connected through the negative pole 178 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 cathode 176, the primary 183 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 to the 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 ~~extension~~ such a voltage at the "grid" 177 that one half cycle should get surpressed.

In the following another method of transcription will be described which only makes use of photographic methods. In figure 17 200 is a light source placed in the focus of a lense 201 projecting parallel light on the analyser 202 and on the section Y of the film 203 on which the piece of music or speech is 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 dx of the film 203 will be concentrated on the corresponding section dx of the first interdediary film. The films 203 and 205 are simultaneously moved through the apparatus, both films moving for instance at the same speed. A given section dx of the film 205 will 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 dx, 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 ~~sound~~ record ~~in the section X~~ of speech or music on film 203. By making a negative 210 (which will be called the second intermediary film) from the film 205 we obtain an extinction curve for a given section dx 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 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 figure 18 but only the mean v alues of the extinction. This is indicated in figure 19.

If film 205 and its "blurred" negative 210 are placed one on top of the other and copied on a third film 211 (which will be called the third intermediary film) one can 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 t he extinction curves shown in figures 18 and 19.

Figure 21 shows 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/~~xxxxxx a section X (which can correspond to 1/10 to 1/40th of a second) of the film 211x/x A cylindrical lense 223 concentrates the light on a small slit 224 in front of whichxthexfilmx205xisxmovingxalong. The light of each section xdxx on the film xxdxofxxitxthexintegralxi~~ 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 will be impressed.

Instead of using a sound generator film as hitherto described one can also use a sound generator disc as shown in figure 22.

In figure 22 230 is the sound generator disc (a glass 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 tempi for instance allegro and a larger basic time for andante. 232 is the modulator film.

In reproducing sound by the arrangement shown in figure 1 one must take care that the width Δy 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 Δy one could increase $1/\mu$ but this is not very convenient for the following reason: if we increase $1/\mu$ 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 Δy 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 <u>larger</u> 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 Δx have the same μ on both films 242 and 244.

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 methods for manufacturing the modulator film which has been described in figure 15a and 15b 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 24 250 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 microphone). The cathode rays, 253 the intensity of which is following the oscillations of the sound, strike a rotating disc 254 at its cylindrical circumference 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 of the disc 254 on the slit 258. An analyser, 259 built in the same way as sound generator films are built, is kept rapidly

m

moving in front of slit 258 in such a way that many waves ~~xxxxx xx xxx xxxxxxx xxxx xxxxxx~~ recorded on the analyser 259 enter the slit 258 while the disc 245 moves only by a fraction of the corresponding 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 ~~xxx~~ one section dx 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 ~~xx~~ mirror 260 so that when mirror 260 is projecting the image of a definite ~~xxxxxxx~~ section x on photocell 261, mirror 264 should project the image of the luminous spot of tube 263 on the corresponding section x of film 265.

PATENTS & DESIGNS ACTS 1907-1932.

Form 2.

PROVISIONAL SPECIFICATION.

REPRODUCTION OF SOUND.

I, LEO SZILARD, of German nationality, of 8, Keeble Road, Oxford, Oxfordshire, do hereby declare the nature of this invention to be as follows:-

The invention concerns a method for registering sound, for instance speech or music by photographic methods for instance on 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.

Hitherto in sound recording, a record has usually been made of the actual wave form of the sound to be recorded, either on a film by the well known variable width or variable density methods, or on a gramophone or similar record. The disadvantage of such records lies in the fact that, in order to record items lasting for any length of time, a large amount of recording material (be it film or wax or like material) has to be used, due to the fact that, in reproduction, the record must pass at a considerable speed through the reproducing device.

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

According to the present invention there is provided a method of recording and reproducing sound wherein a record is made of the changes in amplitude of each frequency (or small band of frequencies) over the whole range of sound to be recorded. These records may be disposed side by side upon a film.

Further according to the present invention there is provided apparatus for producing such records, and for reproducing sound therefrom.

The invention will be illustrated by way of example with reference to the accompanying drawings in which

Figs. 1a and 1b illustrate the principle of the invention,

Figs. 2a, 2b, 4 and 5 illustrate types of records produced according to the present invention,

Fig. 3 is an explanatory diagram,

Figs. 6, 7, 8 and 9 are forms of apparatus or parts thereof, for carrying the invention into effect,

Figs. 10, 11, 11a, 11b, 12, 13 and 14 show further types of records produced according to the present invention,

Figs. 15a, 15b, 16, 17a and 17b show further forms of apparatus or parts thereof,

Figs. 18, 19, 19a and 20 are explanatory diagrams,

Figs. 21, 22a, 22b, 23a, 23b, 24a and 24b are further forms of apparatus according to the present invention.

Referring to Fig. 1, 5 is a film called hereinafter the modulator film on which speech or music is registered by a new method which will be further described 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 Δy of the film 5 which is in front of slit 4, but also a quickly moving endless film 3 which will be called the sound generator. An optical lens 2 renders the light of the light source 1 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.

In Fig. 2a is shown a strip of the film 5. A section Δy 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 1/40th of a second, and which will be called the time basis of reproduction. As shown in Fig. 2a, the section Δy is made up of 11 sections of width across the film Δx. The transparency of each 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 3 at the time when the section Δy 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 will be at least 200. If the number of sections Δx is very large, a continuous curve may be obtained by plotting the transparency of the film 5 as a function of x for a definite section Δy. (In this description y refers to distances longitudinal of the film and x refers to distances transverse of the film.) Such a curve is shown in Fig. 3. It gives the frequency spectrum of the sound at a definite moment within the time basis of reproduction. <u>x</u> need not be a direct measure of the frequency, but the frequency is a function of <u>x</u> ($\nu = f(x)$) the form of which can be chosen to suit requirements. The film 3 is shown in Fig. 2b, and is also divided into 11 sections Δ <u>x</u>, the sections being marked x_1, x_2, x_3 -------- x_{11}. Within each of these sections Δ<u>x</u> the transparency varies along the film as a sinus function of <u>y</u> (transparency = $A(x) \sin 2\pi\mu(x)\, y$). A is a constant for any one section Δx, and varies from one section to another. μ also varies from one section to another, and is a function of <u>x</u>.

If the film 5 were to remain fixed, a given section Δy being in front of the slit 4, and if the film 3 moved past the slit 4 with a velocity <u>v</u> one would hear a sound composed of the 11 frequencies recorded on the film 3, i.e. the frequencies $v\mu x_1$, $v\mu x_2$ -------- $v\mu x_{11}$, each of them with an intensity determined by the transparency of film 5 at the corresponding sections x_1, x_2, x_3 ---- x_{11}. The individual values of the transparency for the corresponding sections Δx 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 moves slowly so that after 1/10 to 1/40th of a second another section Δy 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 number of frequencies (a large number of sections Δx) we can get a very good reproduction of speech or music.

Figure 4 shows the manner in which the intensities are recorded on the modulator film 5. Each section Δx has a transparent section surrounded by two non-transparent sections. The amount of light transmitted by section Δx 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 manner of recording intensities on a modulator film 5. Here we have within each section Δx a "transparent" section between two non-"transparent" sections 51, 52 etc. The breadth of the "transparent" section is constant along the film (it does not vary with y) but the "transparent" section is not completely transparent, its density varies along the film (is a function of y).

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

If the slit 4 has a width of 1/10 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 require 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 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 being narrow at the right hand end where the high frequencies are controlled, and being wider at the left hand end where the lower frequencies are controlled. It is advantageous 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 density along the film and used in combination with a modulator film of the type shown in Fig. 4 or 5. It is, however, possible to reverse the combination and use a modulator film of the variable density type shown in Figure 5, and a sound generator film on which the frequencies are recorded by the variable width method.

It has been mentioned that the number of the sections Δx will be large and can be anything above 200, for instance if the lowest frequency which it is desired to include in the reproduction is 100, and the highest frequency is 5,000, and if it is desired that the difference between two adjacent frequencies v should be about $\Delta v = \frac{v}{100}$; i.e. 1% of the frequency it will be necessary to use about $N = \ln \frac{5000}{100} / \ln (1 + \frac{1}{100})$ frequencies, $\ln \frac{5000}{100}$ is about 4; $\ln(1+ \frac{1}{100}) \simeq 0{\cdot}01$; i.e. $N \simeq 400$.

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 condenser 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 connected to the cathode 71 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 positive pole 79 of the high voltage battery 80 on the one hand and through a condenser 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 amplifier set 93 which feeds the loudspeaker 94.

Figure 8 shows an alternative form of apparatus for reproducing sounds by the method according to the present invention. 101 is a light source placed in the focus of the optical lens 102 which throws parallel light across the slit 104 and the sound generator film 103. A second optical lens 107 projects the image 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 surface and throws a faint image of the film 103 (in front of 104) through the dark filter 109 on the photocell 110. The purpose of the second photocell 110 is the following:

For the recording of sound on the modulator film 5 having variable density along the sections x, it is sometimes difficult to reach a very high density i.e. the transparency of the sections x has a very ~~a very~~ small though finite value even in the absence of the corresponding frequencies in the music or speech which is to be reproduced. Weak light of all frequencies thus reaches the photocell 106 in all circumstances and would produce disturbing sounds. The second photocell 110 gets light direct from the sound generator film and the filter 109 can be so adapted that the current generated by 110 should for every frequency compensate the current generated in 106 by the frequencies which it is not desired to reproduce.

Figure 9 shows how the photocells 106 and 110 are used. 115 is a high voltage battery, the positive pole 116 of which is connected to the anode 117 of the cell 110 and the anode 118 of the cell 106. The cathode 119 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 battery 132, the 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 cathode 121 of the cell 110). Point 127 is connected through the condenser 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 cathodes 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 can be connected to an amplifier set and a loudspeaker.

If the recording of the sound on the modulator film 5 is performed in a manner indicated in Figure 5 it is not necessary to have a limited number of sections Δx isolated from each other by blackened strips 51, 52, 53. Within each section Δy the transparency of the film can be a perfectly continuous function of x. It ~~has~~ is advantageous 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 wavelength is photographed on section x_1 of the film (i.e. the transparency varies with y along section x_1 according to $A(x_1) \sin 2\pi\mu(x)y$; another sinus function of a slightly different wavelength $\mu(x_2)$ is photographed on section x_2. Section x_1 and section x_2 are overlapping as indicated in Figure 10. In the same way a third sinus function is photographed on section x_3, the wavelength $\mu(x_3)$ being again shifted a little against the wavelength of section x_2. Section 3 is overlapping sections x_1 and x_2 in the manner indicated 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 centre of gravity of which will be determined by X. The breadth of the band depends on the breadth D of the sections

x_1, x_2, x_3...., on the shift ϵ of these sections with respect to each other, and on the shift of frequency $\frac{d\mu}{dx}\epsilon$ from one section to another. The breadth of the band v produced by light transmitted at a definite spot x will approximately be

$$\Delta v \approx v \frac{d\mu}{dx} \epsilon \cdot \frac{D}{\epsilon} = v \frac{d\mu}{dx} D.$$

If it is desired to reproduce music it is important that the mean frequency v generated by light transmitted at a definite spot x should be proportional to e x ($\frac{d\mu}{dx} = \alpha\mu$). If this condition is fulfilled ($\mu = Ce^{\alpha x}$) a small shift of the modulator film with respect to the sound generator film in the direction 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 the present 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 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 Yg of the film which corresponds to a certain length of time, say 1/10th to 1/40th of a second which may be called the basic length of time Tg of the sound generator film of this type. If v is the velocity at which the sound generator film is moving then vTg = Yg.

The line 154 indicates the middle of the section Yg. The transparency of the film in the section x_1 is given by a function $A x_1 \cos \mu(x_1)(y-y_0)$, y_0 being the y co-ordinate of the middle of section Yg. This function is shown in Figure 11a. The transparency of the film in the section x_2 (which is shifted in respect of section x_1 by ϵ, and is overlapping section x_1) is given by a function $A(x_2) \cos \mu(x_2)(y-y_0)$, μx_2 being slightly different from $\mu(x_1)$. This function is shown in Figure 11b. The same applies to section x_3 and so on.

The next section Yg between lines 152 and 153 is made exactly like the section g between 151 and 152; again all the functions copied within this section Yg have their maxima in the middle 155 of the section. The same holds for every following section Yg.

The boundaries of the sections Yg need not be parallel to the x axis, but can 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 film 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° 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 possible to manufacture one of the above mentioned types of modulator film from an ordinary record of a piece of music or of speech on an ordinary film, the sound being recorded in one of the two usual types of recording, i.e. by either the variable width or variable density types.

In Figs. 15a and 15b is illustrated a method for transcribing this usual type of record into a sound record on the modulator film of one of the types mentioned above. 160 is a film similar to the sound generator films as described above. 161 is the film on which a piece of music or speech is recorded in one of the two usual ways. The light emerging from the light source 162 placed in the focus of the optical lens 163, is rendered parallel thereby and thrown through a section Y_R of the sound generator film 160 and of the film 161. The length Y_R corresponds on the record 161 to the basic length of time T_R of the operation of recording. While a certain section of the record 161 is in front of the window 164, the film record 161 being at rest, the film 160 which will be called the "analyser" is kept moving. The light transmitted by the section Y_R of both films is collected by the lens 165 and thrown on the photocell 166. As shown in Figure 15b the window 164 admits only light across a small section dx 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. With a given section dx of the analyser (representing a given mean frequency $\mu(x)$) in front of the window 164 and with the analyser 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 $\mu(x)$ 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 $\mu(x)$ on the film record 161. If the alternating current 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 dx of the film 169 the transparency of the section dx will be determined by the intensity of the oscillation $\mu(x)$ 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 164 and at the same time different spots x of the film 169 are brought in front of the slit 168. At each section dx at the spot x of the film 169, the intensity of the corresponding oscillation $\mu(x)$ on the film record 161 is 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 and the record 169 are at a standstill. During this motion the film 161 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 instance 1/10, of the basic length Y_R of the transcription operation. Then 161 and 169 are again shifted forwards and backwards 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 may be amplified in any suitable manner. In Fig. 16 is illustrated apparatus whereby recording may be carried out by means of a Braun tube. The electrons emitted by the filament 176 of a Braun tube 175 are controlled by the cylinder 177 which is connected to the negative pole 178 of a small battery 179, the positive pole 180 of which is connected to the secondary winding 181 of a transformer 182. The other pole of the secondary winding 181 is connected to the cathode 176, the primary 183 of the transformer being connected to the amplifier of the signals from the cell 166 of Fig. 15a. 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 to the pole 187 of the high voltage battery 188. The positive pole 189 of the battery 188 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 rectifier in the same way as an audion. The battery 179 maintains such a voltage at the "grid" 177 that one half cycle should get suppressed.

In the following another method of transcription will be described which only makes use of photographic methods. In Figs. 17a and 17b 200 is a light source placed in the focus of a lens 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 is recorded in one of the two usual ways of recording. A cylindrical lens 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 dx of the film 203 will be concentrated on the corresponding section dx 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 dx of the film 205 may show after being developed a density 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 oscillation shown in the density curve is determined by the amplitude of the oscillation of the corresponding frequency in the record of speech or music on film 205. By making a negative 210 (which will be called the second intermediary film) from the film 205 a density curve for the given section dx of the negative may be obtained as shown in Fig. 19. Fig. 19 corresponds to the density curve of the film 205 shown in Fig. 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 parallel to the y axis. The divergency should be greater for sections dx which correspond to lower tones. If copying is done in this way, the negative 210 will not show the oscillations of Figure 18 but only the mean values of the density. This is indicated in Figure 19.

If film 205 and its "blurred" negative 210 are placed one on top of the other and copied on a third film 211 (which will be called the third intermediary film) a hard copy can be obtained by using a suitable developer such as one containing potassium bichromate. Figure 20 shows such a copy which corresponds to the extinction curves shown in Figures 18 and 19.

Figure 21 shows how to transcribe the third intermediary film 211 into the modulator film 212 which is needed for the present system of reproduction. 220 is a light source placed in the focus of a lens 221 which makes its light parallel and throws it across the slit 222 and the third intermediary film 211 on to the film 212. While the film 211 is moving quickly the film 212 moves slowly and on a single section dy of the film 212 in front of the slit 222 a large number of individual humps (shown in Figure 19) of the film 211 will be impressed.

Instead of using a sound generator film as hitherto described a sound generator disc may be used in the manner illustrated with reference to Figs. 22a and 22b.

230 is the sound generator disc (a glass 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). In practice it is preferable to use a smaller basic time for a quick tempo, for instance allegro, and a larger basic time for andante. 232 is the modulator film.

In reproducing sound by the arrangement shown in Figure 1 care must be taken that the width y of the slit 4 should be small enough in relation to the smallest wavelength $1/\mu$ photographed on the sound generator film 3. If it is desired to use a wider slit Δy, $1/\mu$ could be increased, but this is not very convenient for the following reason: if $1/\mu$ is increased, the velocity v at which the sound generator film moves must be increased 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 whereby a larger y may be used for the same sound generator film. In Figs. 23a and 23b there is shown a light source 240, the light of which is made parallel by the lens 241 and thrown on the slit 243, the width dy of which may be larger than the smallest wavelength $1/\mu$ on the sound generator film if the arrangement as described in the following is used: 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 exactly like the sound generator film 242 only at rest in front of the window. (Each individual section Δx has the same value of μ on both films 242 and 244.) The light transmitted by the slit 243 traverses the modulator film 245 and enters the photocell 246. The current generated by the photocell may be used to operate a loudspeaker.

The method for manufacturing the modulator film which has been described in Figure 15a and 15b makes 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 the present system of sound reproduction. In Figs. 24a and 24b is illustrated a direct method of obtaining the modulator film which has the great advantage that an ordinary sound film (which is very long as compared to the modulator film)need not be made.

250 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 microphone). The cathode rays 253, the intensity of which follow the oscillations of the sound, strike a rotating disc 254 at its cylindrical circumference 255 which is coated by a luminescent phosphor. For this purpose a phosphor is chosen which has a sufficiently long after-glow. 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 of the disc 254 on the slit 258. An analyser 259 formed in the same way as sound generator films are formed, is kept rapidly moving in front of slit 258 in such a way that many waves recorded on the analyser 259 pass across the slit 258 while the disc 245 moves a distance which is only a fraction of the corresponding wavelength (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 <u>x</u> co-ordinate and a function of the <u>y</u> co-ordinate which shows the oscillations of the sound. The section 257 bears a record of the sound to be recorded similar to that of an ordinary sound film, for instance as in Figure 15. A mirror 260 in front of the slit 258 projects the image of the slit on a photocell 261. The mirror oscillates rapidly about the axis 262, thereby projecting one section dx 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 quick in comparison with the motion of the disc 254. The photocell 261 controls a cathode tube 263 in the same way as described with reference to Figure 15. The luminous spot of the cathode tube 263 is projected by the mirror 264 on the film 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 x on photocell 261, mirror 264 should project the image of the luminous spot of tube 263 on the corresponding section x of film 265.

Dated this day of 1935.

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