Oct. 12, 1926. 1,602,469

E. F. WATSON ET AL

ELECTRICAL TRANSMISSION OF PICTURES

Filed Dec. 20, 1923 4 Sheets-Sheet 1

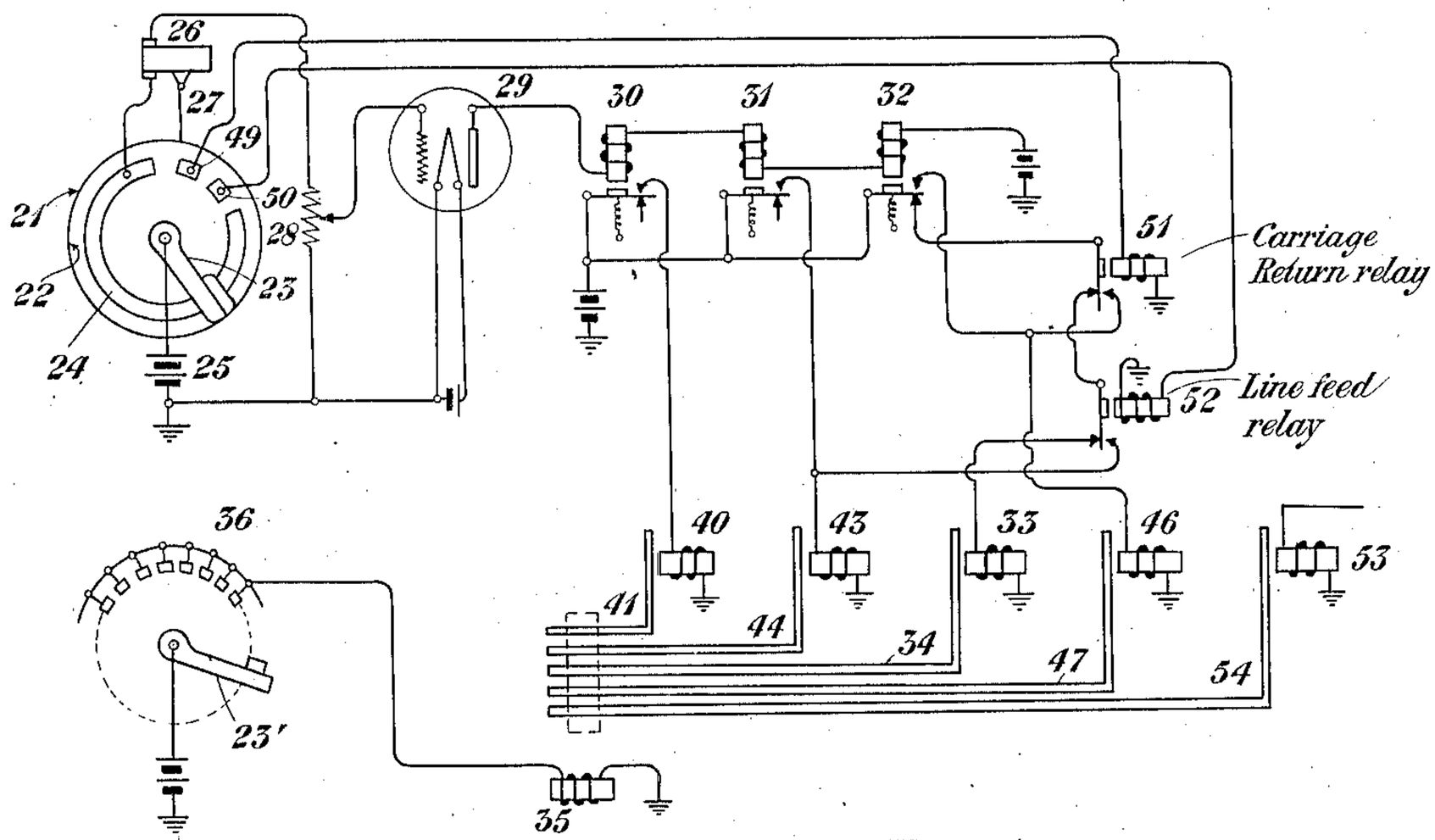



Fig. 1

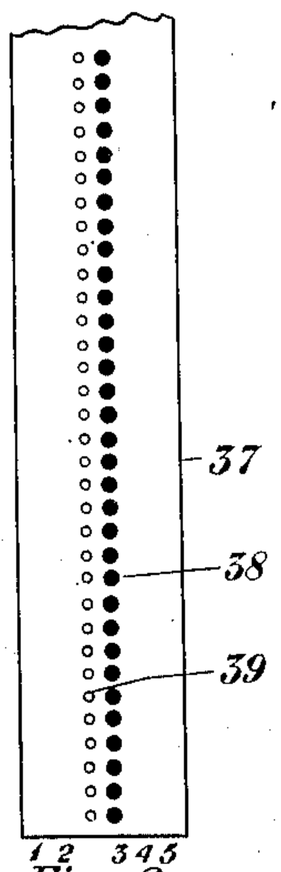



Fig. 2

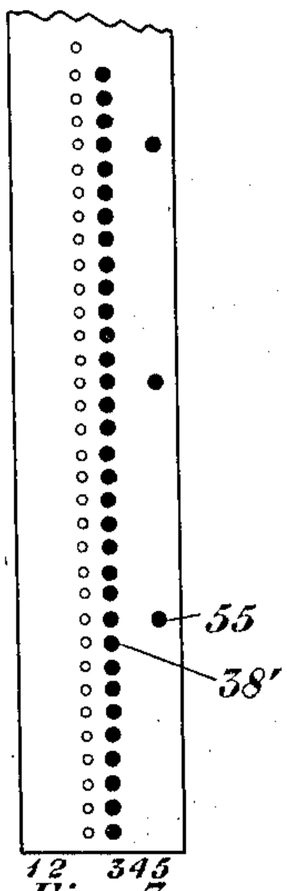



Fig. 3

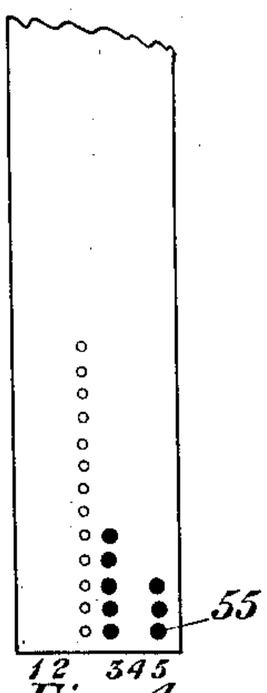
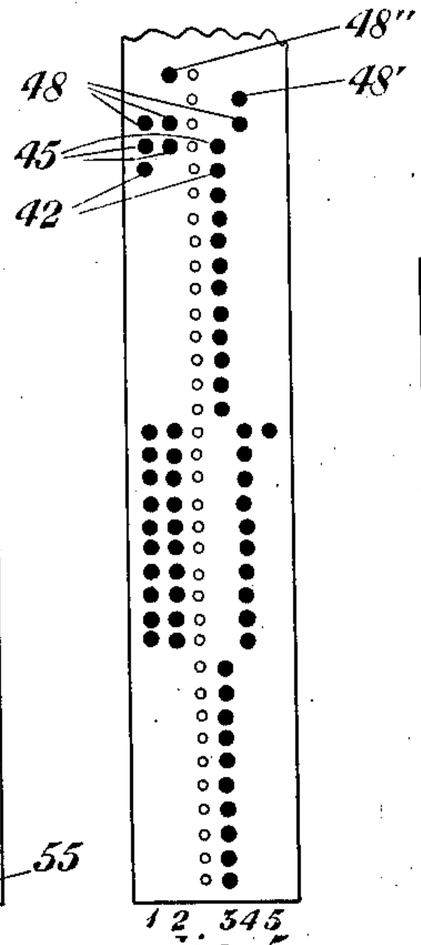



Fig. 4




ig. 5

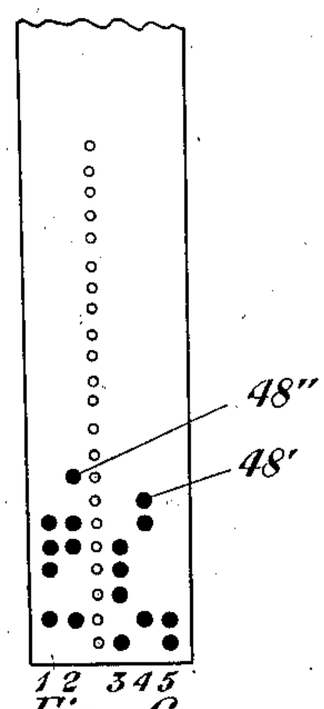



Fig. 6

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ELECTRICAL TRANSMISSION OF PICTURES

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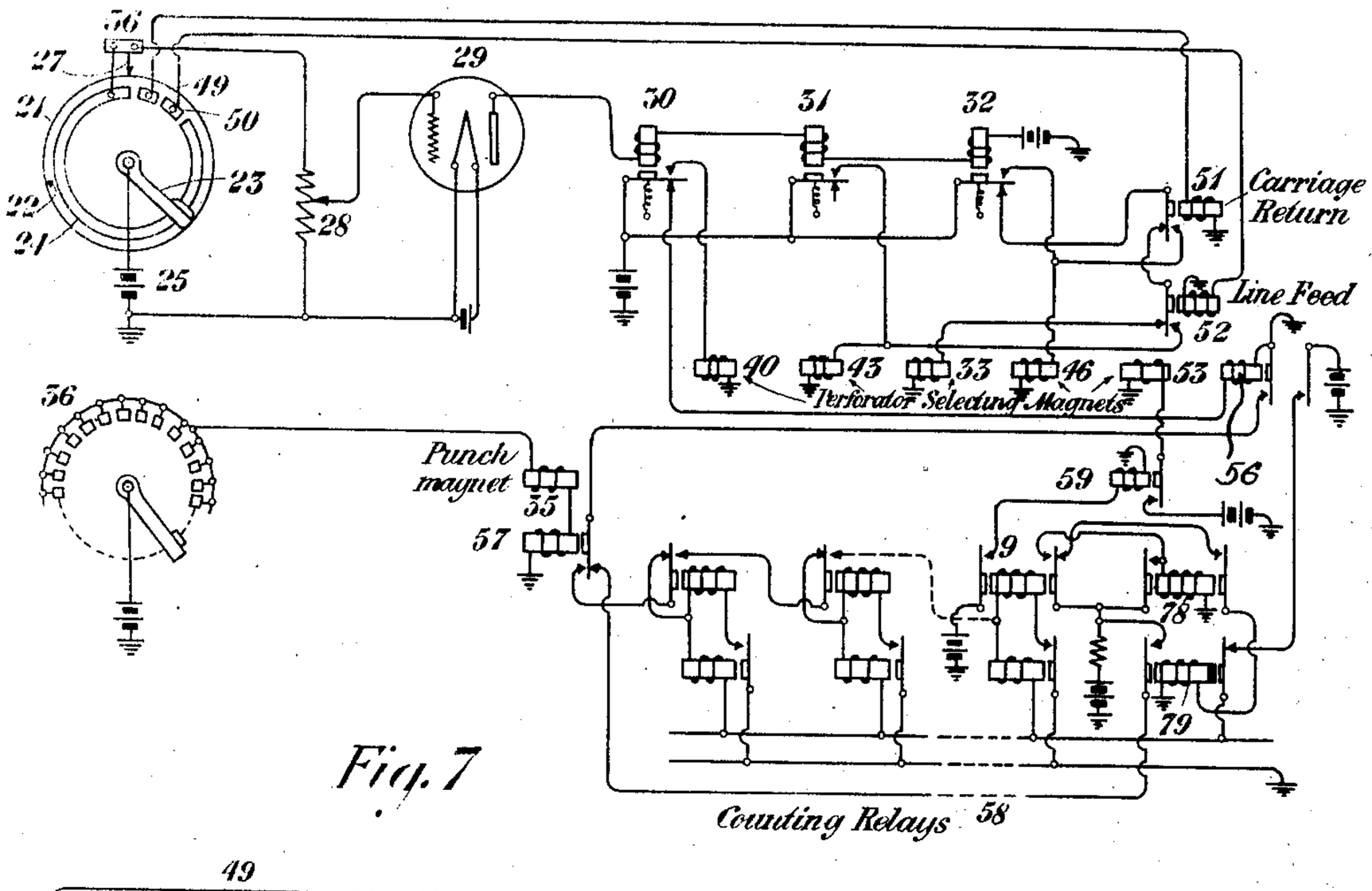


Fig. 7

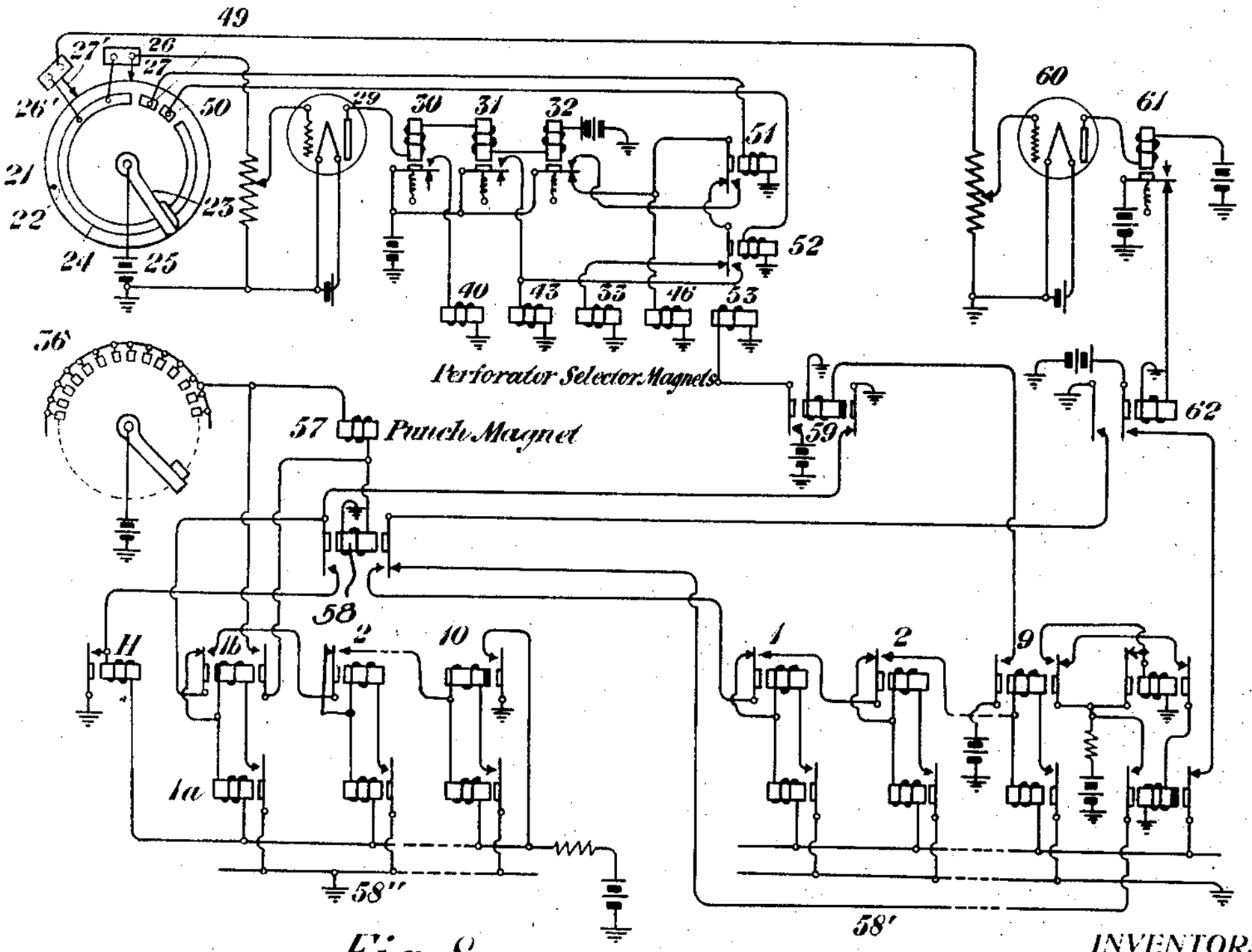


Fig. 8

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ELECTRICAL TRANSMISSION OF PICTURES

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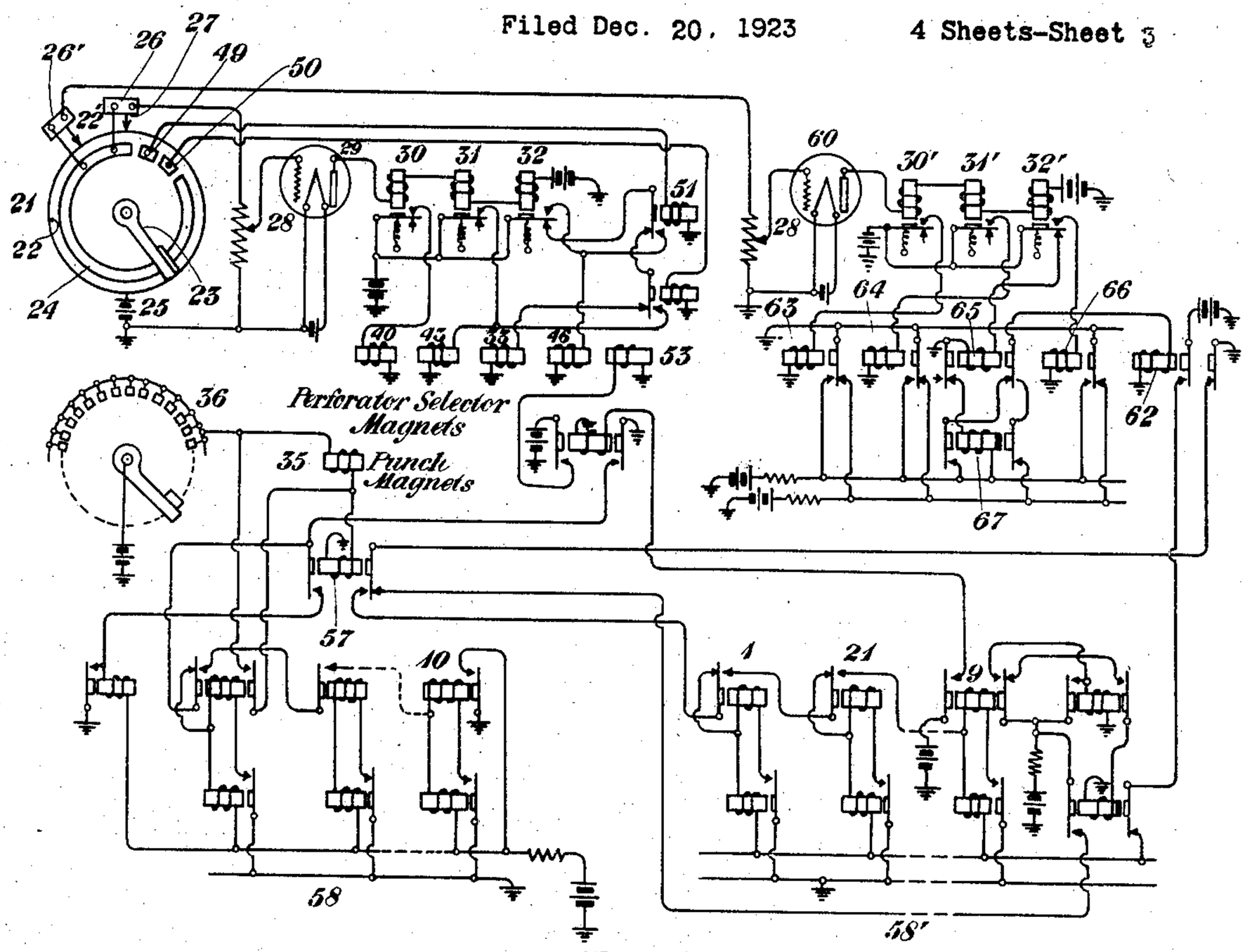


Fig. 9

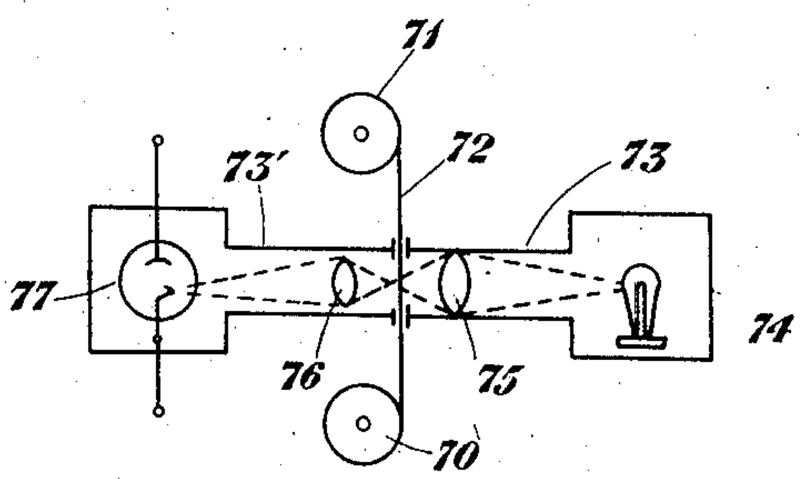


Fig. 10

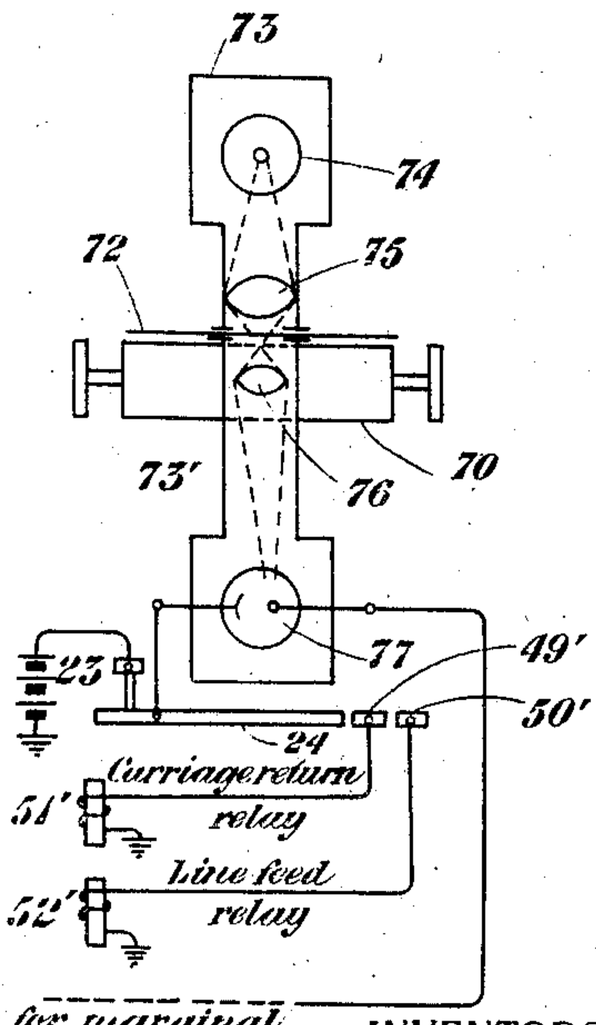


Fig. 11

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Oct. 12 , 1926. 1,602,469

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ELECTRICAL TRANSMISSION OF PICTURES

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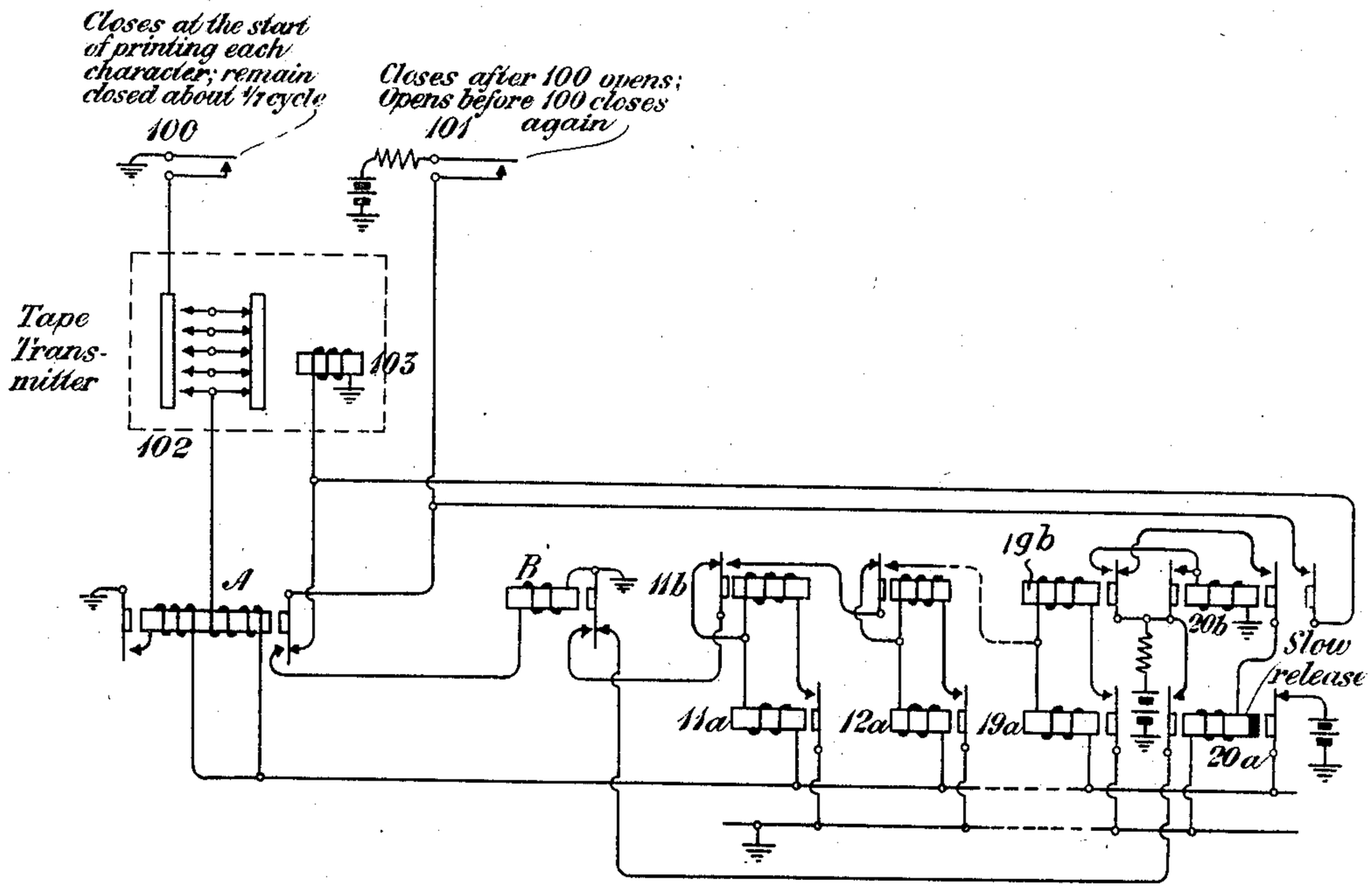


Fig. 12

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Patented Oct. 12, 1926. 1,602,469

# UNITED STATES PATENT OFFICE.

EDWARD F. WATSON, OF LARCHMONT, AND ALLAN WEAVER, OF BROOKLYN, NEW YORK, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

## ELECTRICAL TRANSMISSION OF PICTURES.

Application filed December 20, 1923. Serial No. 681,853.

The principal object of our invention is to provide a new and improved method and suitable apparatus for electrically transmitting pictures to a distance. Another object of our invention is to provide for analyzing a picture into small elemental portions and transmitting code symbols to indicate the shade of these respective portions, and from these code symbols at the receiving end to reconstruct the picture. One object of our invention has to do with economizing the use of the transmission line for a sequence of picture elements of the same shade. Another object of our invention has to do with utilizing page printing telegraph apparatus for picture transmission. All these and various other objects of our invention will become apparent on consideration of a limited number of specific embodiments thereof which we have chosen for illustration in the accompanying drawings and to be described in the following specification. It will be understood that the invention is defined in the appended claims and that the following description relates to the particular examples of its practice which are here set forth for illustration.

Referring to the drawings, Figure 1 is a diagram of apparatus for automatically preparing a punched tape to represent the picture. Figs. 2 to 6 are views of punched tapes obtained under various circumstances that will be stated. Fig. 7 corresponds to Fig. 1 with the addition of counting mechanism to count and record on the tape a sequence of picture elements of the same shade. Fig. 8 corresponds to Fig. 7 with the addition of apparatus to suspend punching the tape with individual symbols for individual picture elements when a certan number of those elements are all alike and to punch a special symbol for the entire group. Fig. 9 corresponds to Fig. 8 except that it shows counting and punch suspending apparatus for two shades instead of merely one. Figs. 10 and 11 are, respectively, elevation and top plan views of a detail modification. Fig. 12 is a diagram of receiving apparatus to reproduce the picture from a tape corresponding to the transmitting apparatus of Fig. 9.

Referring to Fig. 1, the rotating drum 22 has a relief film 21 wrapped round it, the degree of relief corresponding with the lights and shades of the picture to be transmitted. The drum 22 is rotated and at the same time traversed relatively slowly in the direction of its axis, so that the stylus 27 in engagement with the film 21 traces on the cylindrical film 21 a helical path.

The shaft carrying the drum 22 also carries a rotating wiper 23 in engagement with a fixed conductive segment 24 whereby the circuit of the battery 25 is completed through the wiper 23 and the segment 24 to the carbon microphone 26 whose resistance is governed by the stylus 27. The current from the battery 25 will vary in accordance with the relief of the film 21 as it is engaged by the stylus 27, and this varying current through the resistance 28 will vary the electromotive force on the grid of the three-electrode vacuum tube amplifier 29.

The output or plate current from the amplifier 29 goes through the three relays 30, 31 and 32 in series. These are marginal relays. None of them picks up for a current corresponding to a degree of relief of the film 21 corresponding, in turn, to white in the picture. For light grey, the output current from the amplifier 29 will be enough to cause 30 only to pick up. For dark grey, the current will be enough to cause relays 30 and 31, but not 32, to pick up, and for black in the picture the current from the amplifier 29 will be enough to cause all three relays 30, 31 and 32 to pick up.

The well known five-unit printing telegraph code is employed except that certain combinations represent different shades of picture elements instead of representing letters of the alphabet as in printing telegraphy.

A length of tape 37 is shown in Fig. 2. This is fed step-by-step in the direction of its length by a star wheel engaging the perforations 39. The five plungers 41, 44, 34, 47 and 54 of Fig. 1 correspond to the five positions indicated by the numerals 1, 2, 3, 4 and 5 in Fig. 2. The drum 22 rotates step-by-step carrying the wiper 23′ one step at a time across successive contact segments 36.

At each such step the punch magnet 35 is normally operated, and it punches in the tape 37 a transverse row of five holes or less corresponding to the plungers 41, 44, 34, 47 and 54 that are actuated by energization of their respective magnets. Operation of the punch magnet 35 also operates the star wheel to drive the tape 37 by engagement with its perforations 39.

Assume that a portion of the film 21 of relief corresponding to white in the picture is passed step-by-step under the stylus 27; accordingly none of the three marginal relays 30, 31 and 32 is actuated. It will readily be seen that of the magnets 40, 43, 33 and 46 only 33 has its circuit closed. This will advance the bar 34, and the punch magnet 35 will punch a series of holes 38 in the third position as in Fig. 2.

When the shade is light grey, marginal relay 30 will be actuated to close the circuit of relay 40 and advance the bar 41 in addition to 34, and the record punched in the tape 37 will be as shown at 42 in Fig. 5.

When the picture shade is dark grey, both marginal relays 30 and 31 will be actuated, and the bars 41 and 44 will be advanced in addition to 34, and the symbol punched in the tape 37 will be as shown at 45 in Fig. 5.

When the picture shade is black, all three marginal relays 30, 31 and 32 are energized, the circuit for 33 will be broken at 32, and the circuit for 46 will be made at 32 so that the record will be made as shown at 48 in Fig. 5. It is assumed that the bars 41, 44, 34, 47 and 54 and the punch magnet 35 are the usual parts in a well known five-element printing telegraph tape-punching machine in which the code combinations 38, 42, 45 and 48 correspond to certain letters or other characters according to the following table:

| Shade of element in picture. | Current strength in marginal relays. | Relays actuated. | Selecting bars advanced. | Code (dashes indicate spaces). | Corresponding regular printer characters. | Modified characters for recording picture. |
|---|---|---|---|---|---|---|
| White. | Lowest. | None. | 34. | — —o— — | Space. | Space. |
| Light grey. | Next to lowest. | 30. | 41 and 34. | o—o— — | S. | Small dot. |
| Dark grey. | Next to highest. | 30 and 31. | 41, 44 and 34. | ooo— — | U. | Medium dot. |
| Black. | Highest. | 30, 31 and 32. | 41, 44 and 47. | oo—o— | J. | Heavy dot. |
| — | — | 51. | 47. | — — —o— | "Carriage return." | "Carriage return." |
| — | — | 52. | 44. | —o— — — | "Line feed." | "Line feed." |

In the foregoing table it will be seen that in addition to the four picture shades, code combinations appear for "carriage return" and "line feed." It is assumed, as will be described presently, that at the receiving end the picture is recorded on a page printing telegraph receiver. At each rotation of the wiper 23 at the transmitting end it engages momentarily the segments 49 and 50, actuating the carriage return relay 51 and the line feed relay 52 and punching the holes in the tape as indicated in the last two lines of the foregoing table and as shown at 48′ and 48″ in Figs. 5 and 6.

At the receiving end a page printing telegraph receiver is employed with a reduced line feed to bring the lines close together and with the letters S, U and J replaced, respectively, by type to make a small dot, a medium dot, and a large dot. Thus it will be seen that the page in the receiving printer reproduces the lights and shades of the picture in four degrees of shade, white, light grey, dark grey and black, giving a "half tone" picture. When viewed at a distance or when reduced photographically, this makes a very good half tone picture.

It will readily be understood that in many pictures there will be considerable regions of uniform shade for which with the apparatus of Fig. 1 the symbols punched in the transmitting tape will be repeated alike for considerable length as, for example, for a white shade in Fig. 2. Preliminary to disclosing how the length of the tape, and accordingly the line time, can be economized for these repetitions of like shade, we will describe in connection with Fig. 7 apparatus for counting and recording in the tape groups of ten successive white picture elements. Fig. 7 is substantially like Fig. 1 with the addition that the magnet 53 for the fifth selecting bar 54 is connected to counting apparatus, and the back contact of the first marginal relay 30 is connected to magnet 56 which controls said counting apparatus now to be described.

Whenever white picture elements are being repeated, as in Figs. 2 and 3, the magnet 56 will be energized and close battery and ground for the counting relays 58. Each time the punch magnet 35 operates, the relay 57 in series therewith will operate momentarily and cause a counting relay to pick up and lock up. There are nine of these counting relays numbered from 1 to 9, and when the ninth hole for the white shade is punched in the tape, as at 38′ in Fig. 3, the relay 9 of assembly 58 will pick up and close the circuit for relay 59 which in turn will close the circuit for relay 53 and advance the bar 54 (referring to Fig. 1)

so that on the next operation of the punch magnet 35, the record on the tape will appear as at 55 in Fig. 3.

When the relay 9 of assembly 58 was energized, it closed a circuit for relay 78 which locked up through a front contact. The 10th operation of relay 57 causes magnet 9 to release which closes a circuit for the slow-release relay 79 which opens the circuit from battery to the counting relays and releases them. The 10th release of 57 shorts out relays 78 and 79 which allows them to release and the system is ready to begin another count. The relay 79 is made slow-release to insure that it releases later than relay 78.

If at any time during a count of a sequence of white picture elements, the shade changes short of ten such elements, the relay 30 will thereupon break the circuit of magnet 56 which in turn will release the circuits for the counting relays, and they will go back to their initial condition.

With the preceding explanation of Fig. 7, it will now be convenient to explain, in connection with Fig. 8, how the tape is shortened by omitting like repeated records for the white shade. The apparatus of Fig. 8 is much the same as for Fig. 7. There is added another carbon microphone 26′ actuated by a stylus 27′ engaging the film ten steps in advance of the stylus 27, that is, a picture element passes under the stylus 27′ ten steps before it passes under the stylus 27. The current through the microphone 26′ goes to the amplifier 60, whose output goes to the relay 61 which is actuated for every shade darker than white, but not by white. Accordingly for a sequence of white picture elements passing under the stylus 27′ the armature of relay 61 remains on its back contact and keeps the relay 62 energized, closing the circuits for the counting relays 58′ which are like 58 in Fig. 7. When the relays 58′ have counted up to 9, relay 9 closes the circuit for relay 59; and on the next impulse the fifth hole 55 is punched along with the third hole to indicate ten units of white shade. Thus as a succession of 10 white elements pass stylus 27′, the first of these comes under stylus 27 and the next punching operation punches the number 3 to indicate white shade and also the number 5 to indicate 10 units of this shade.

When the relay 59 is energized, following the 9th element of white shade to pass 27′, it closes a circuit that begins the count for the counting relays 58″, and the first relay $1^a$, of the assembly 58″, operates and locks up. Relay H operates in parallel with relay $1^a$ and locks. Then the next punching operation punches holes 3 and 5 in the tape as explained above, and relays 9 and 59 release. Then when relay 59 releases, $1^b$ operates and closes a shunt around the punch magnet 57. Therefore the punch magnet is arrested until the count of 10 elements past stylus 27 is completed. Then the next release of relay 57 operates relay 10 of group 58″, releasing this group. In this way the record shown in Fig. 3, as made by the apparatus of Fig. 7, is reduced to the record shown in Fig. 4, as made by the apparatus of Fig. 8.

It will be seen that the shortening of the tape as in Fig. 4 compared with Fig. 3, will result in a decided saving of line time in transmission.

The foregoing explanation of Figs. 7 and 8 shows that for apparatus arranged in accordance therewith, the economy of tape and of line time is practiced only for the white shade. This is likely to be one of the commonest shades in a picture, the next most common shade being black, and the intermediate shades less common. In Fig. 9 a further modification is shown for counting and shortening the tape for repeated picture elements of either white shade or black shade. Fig. 9 corresponds substantially with Fig. 8 except for certain additions that will now be pointed out. Instead of a single marginal relay 61, as in Fig. 8, a plurality of marginal relays 30′, 31′ and 32′ are employed. It will be seen in Fig. 9 that the relays 63, 64, 65 and 66 are so controlled by the marginal relays 30′, 31′ and 32′ that the relay 62 is energized when none of the relays 30′, 31′ and 32′ is energized and when all of them (particularly 32′) are energized. Accordingly the relay 62 is operated both for the white shade and the black shade and the counting relays 58′ and 58″ are operated for either shade. Fig. 5 shows how a tape would be punched with counting, but without shortening, for 10 white impulses, then 10 black impulses, then 10 white, followed by one light grey, one dark grey, one black, "carriage return", and "line feed". With the appartus of Fig. 9, this would be shortened as shown in Fig. 6.

Figs. 10 and 11 show a modification at the sending end. Instead of the apparatus shown in Figs. 1, 7, 8 and 9 in series with the battery 25 and resistance 28, we may introduce the terminals of the photoelectric cell 77 in the circuit of that battery and resistance. In this case 70 is the regular carriage of a printing telegraph machine, used to provide means for moving the film so that it can be tested element by element and line by line. An auxiliary carriage 71 is mounted above it, and the film 72 passes between them. A housing, consisting of two parts 73 and 73′ fitting close to the film on opposite sides thereof, is provided. In the part 73 is the light source 74 and the lens 75 to direct a beam of light through a

narrow spot of the film 72. In the part of the housing 73′ is another lens 76 which directs the beam of light to the photoelectric cell 77. Accordingly the current in the circuit of the cell 77 is made to vary in correspondence with the light striking the cell which in turn varies in accordance with the degree of transparency of the part of the film 72 interposed in the path of the light.

In this case the straight conductive bar 24′ takes the place of the segment 24 of Fig. 1 and is engaged by the contact 23′ which travels with the carriage, and at the end of each line of travel of the carriage the contact 23′ engages the contacts 49′ and 50′ and actuates the carriage return relay 51′ and the line feed relay 52′.

Suitable receiving apparatus is indicated or shown in Fig. 12. The tape at the transmitting end abbreviated as described, is used to send code impulses over the line, and by means of these a similar tape is reproduced at the receiving end. This received tape is then fed to a tape transmitter 102 controlling a page printer which prints the picture, element by element in succession, according to the code given earlier in this specification; that is the code for white prints blank, the code for light grey prints a small dot, the code for dark grey prints a medium dot, and the code for black prints a heavy dot. But whenever the tape contains a hole in the fifth position this means that the shade indicated by the corresponding code shall be printed ten times. The apparatus by which this is effected is shown in Fig. 12.

When there is no hole in the fifth position in the tape, the operation of the tape transmitter is normal and the feed magnet 103 is energized for each revolution of the sending distributor brush which is equivalent to each operation of the recording printer. However, when there is a hole in the fifth position of the tape, a circuit is completed from the ground through contact 100 on the start relay and through relay A to battery. This operates relay A which locks up and transfers the normal tape feeding circuit from the feed magnet 103 to relay B. Then, as the first character is printed, relay B is energized from battery through contact 101. This causes the operation of relay $11^a$ and, as soon as B releases, operates relay $11^b$. Similarly, as the second character is printed relays $12^a$ and $12^b$ are operated. On the printing of the ninth character, relays $19^a$ and $19^b$ operate in a similar manner and when $19^b$ operates, it causes the operation of relay $20^b$ which locks through a front contact. Then, as the tenth character prints, relay B is again energized and relay $19^b$ is released, causing the operation of relay $20^a$ which releases all of the counting relays excepting $20^a$ and $20^b$ and also releases relay A. This, in turn, releases relay B which, through its back contact, releases relays $20^a$ and $20^b$ so that the system is restored to normal for the 11th character. In the meantime, the operation of relay $20^b$ has closed the regular tape feeding circuit including magnet 103, so that the tape has stepped forward to the next code while the tenth character was being printed.

We claim:

1. Means to automatically transmit electrical currents corresponding to the degrees of light and shade in a succession of picture elements, and means to send a modified current for a succession of elements of like shade and thereby economize the time of transmission.

2. Means to punch a tape with symbols corresponding to the degrees of light and shade in a succession of picture elements, and means to punch in said tape a single code symbol for a succession of picture elements of like shade whereby the length of the tape is shortened for repeated picture elements of like shade.

3. Means to automatically transmit electrical currents corresponding to the degrees of light and shade in a succession of picture elements, means to count a succession of picture elements of like shade, and means to transmit a current of special character corresponding to the result of such a count, said special current indicating the degree of shade of the counted elements and their number.

4. A picture film varying in character to represent the lights and shades of the picture, a plurality of exploring means for simultaneously exploring separate elements of said film, a plurality of marginal relays controlled by certain of said exploring means, and means to punch a tape in correspondence with the operation of the marginal relays.

5. In a picture transmitting system employing a punched tape and a page printer at the receiving end, means to prepare the tape at the sending end comprising relays to punch carriage return and line feed symbols in the tape, and a commutator operated in connection with the transmitting film to actuate said relays at the end of each cycle of movement of the transmitting film.

6. Means to prepare a perforated tape for the transmission of a picture, comprising means to punch a distinctive set of holes in the tape corresponding to distinguishable shades in the respective picture elements, means to count a definite number of like shaded picture elements in succession, and means to punch a distinctive set of holes in the tape upon the completion of such a count.

7. Means to prepare a perforated tape for the transmission of a picture comprising means to punch a distinctive set of holes in the tape corresponding to distinguishable

shades in the respective picture elements, means to count a definite number of like shaded picture elements in succession, means to punch a distinctive set of holes in the tape upon the completion of such a count, and means to release the counting mechanism and restore it to initial condition when the shade changes short of the completed count.

8. Means to prepare a perforated tape for transmitting a picture comprising primary means to explore a picture film passing successively from element to element thereof, auxiliary exploring means a certain number of elements in advance of said primary means, counting means controlled by said auxiliary exploring means, means to punch a distinctive symbol in the tape when the said auxiliary exploring means counts up to the number of intervening picture elements, and means to arrest the further punching of the tape while that same number of elements is explored by the primary exploring means.

9. Means to prepare a perforated tape for picture transmission comprising means to punch the tape distinctively in correspondence with the degree of shade of successive picture elements, means to count in advance a sequence of picture elements of like shade and upon the completion of such count to punch a distinctive symbol in the tape, and means thereupon to arrest the further punching of the tape for such sequence of like picture elements.

10. Means to explore a picture element by element for the degrees of shade thereof, a plurality of devices adapted to respond respectively for the different degrees of shade, and means controlled by said devices to record code combinations for the respective degrees of shade, said last mentioned means being adapted to make a single record indicating the number and shade of the elements in the sequence.

11. A picture film varying in character to represent the lights and shades of the picture, means to explore simultaneously a plurality of elements of said film, a plurality of marginal devices controlled by said means, and means to make a code record in correspondence with the operation of the marginal devices.

12. The method of electrically transmitting a picture which consists in automatically sending electric currents corresponding to successive picture elements and sending special modified currents for a sequence of picture elements of like shade and thereby economizing the time of transmission.

13. The method of electrically transmitting a picture which consists in automatically sending code combinations corresponding to the degree of shade of successive picture elements, automatically counting a sequence of picture elements of like shade, and sending a special code on the completion of such count, said special code indicating the shade and number of the counted elements.

14. The method of electrically transmitting a picture which consists in automatically sending code impulses corresponding to the degree of light and shade in successive picture elements, automatically counting a definite sequence of picture elements of like shade and sending a special code combination for such sequence instead of successive like impulses for the elements thereof.

15. The method of electrically transmitting a picture which consists in testing its elements successively for degree of shade, automatically counting a sequence of elements of like shade, making a single record of the results of said count, automatically sending code impulses controlled by said single record to indicate the shade and also to indicate the count as aforesaid, and reproducing the picture element by element from the received code impulses.

16. The method of electrically transmitting a picture which consists in testing its elements successively for degree of shade, automatically counting a sequence of elements of like shade, making a single record in code symbols to indicate the shade and also to indicate the count as aforesaid, automatically transmitting currents determined by said code symbols, and reproducing the picture element by element from the received currents.

17. The method of electrically transmitting pictures which consists in simultaneously testing a plurality of separate picture elements, sending currents in accordance with the tone value of one element being tested, recording the tone value of another element being tested, and subsequently sending currents in accordance with the recorded test.

18. The method of electrically transmitting a picture which consists in making a plurality of tests of the same picture elements, sending currents in accordance with the results of one test and simultaneously recording results of the other test and subsequently sending currents in accordance with said other test.

19. In a picture transmission system, means for exploring successive elements of a picture to be transmitted, means for automatically making a single abbreviated code record of the number of elements in a sequence of like shade and of the degree of said shade.

20. In a picture transmission system, means for testing elements of the picture to be transmitted, means for automatically sending code currents corresponding both to the number of elements in a sequence of like shade and to the shade of the elements

of said sequence, means to receive said currents, and means to reproduce said picture in accordance with said received currents.

21. In a picture transmission system, means for exploring successive elements of a picture to be transmitted, means for counting the number of elements in a sequence of like shade, and means for automatically making a record in the form of a single code combination of the number of counted elements and their degree of shade.

In testimony whereof, we have signed our names to this specification this 19th day of December, 1923.

EDWARD F. WATSON.
ALLAN WEAVER.

# DISCLAIMER

1,602,469.—*Edward F. Watson*, Larchmont, and *Allan Weaver*, Brooklyn, N. Y. ELECTRICAL TRANSMISSION OF PICTURES. Patent dated October 12, 1926. Disclaimer filed September 12, 1934, by the assignee, *American Telephone and Telegraph Company*.

Hereby enters this disclaimer to the said claims of said Letters Patent which are in the following words to wit:

"1. Means to automatically transmit electrical currents corresponding to the degrees of light and shade in a succession of picture elements, and means to send a modified current for a succession of elements of like shade and thereby economize the time of transmission.

"2. Means to punch a tape with symbols corresponding to the degrees of light and shade in a succession of picture elements, and means to punch in said tape a single code symbol for a succession of picture elements of like shade whereby the length of the tape is shortened for repeated picture elements of like shade.

"3. Means to automatically transmit electrical currents corresponding to the degrees of light and shade in a succession of picture elements, means to count a succession of picture elements of like shade, and means to transmit a current of special character corresponding to the result of such a count, said special current indicating the degree of shade of the counted elements and their number."

"6. Means to prepare a perforated tape for the transmission of a picture comprising means to punch a distinctive set of holes in the tape corresponding to distinguishable shades in the respective picture elements, means to count a definite number of like shaded picture elements in succession, and means to punch a distinctive set of holes in the tape upon the completion of such a count.

"7. Means to prepare a perforated tape for the transmission of a picture comprising means to punch a distinctive set of holes in the tape corresponding to distinguishable shades in the respective picture elements, means to count a definite number of like shaded picture elements in succession, means to punch a distinctive set of holes in the tape upon the completion of such a count, and means to release the counting mechanism and restore it to initial condition when the shade changes short of the completed count."

"10. Means to explore a picture element by element for the degrees of shade thereof, a plurality of devices adapted to respond respectively for the different degrees of shade, and means controlled by said devices to record code combinations for the respective degrees of shade, said last mentioned means being adapted to make a single record indicating the number and shade of the elements in the sequence."

"12. The method of electrically transmitting a picture which consists in automatically sending electric currents corresponding to successive picture elements and sending special modified currents for a sequence of picture elements of like shade and thereby economizing the time of transmission.

"13. The method of electrically transmitting a picture which consists in automatically sending code combinations corresponding to the degree of shade of successive picture elements, automatically counting a sequence of picture elements of like shade, and sending a special code on the completion of such count, said special code indicating the shade and number of the counted elements.

"14. The method of electrically transmitting a picture which consists in automatically sending code impulses corresponding to the degree of light and shade in successive picture elements, automatically counting a definite sequence of picture elements of like shade and sending a special code combination for such sequence instead of successive like impulses for the elements thereof."

"19. In a picture transmission system, means for exploring successive elements of a picture to be transmitted, means for automatically making a single abbreviated code record of the number of elements in a sequence of like shade and of the degree of said shade."

"21. In a picture transmission system, means for exploring successive elements of a picture to be transmitted, means for counting the number of elements in a sequence of like shade, and means for automatically making a record in the form of a single code combination of the number of counted elements and their degree of shade."

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