March 28, 1933. F. C. P. HENROTEAU 1,903,112

TELEVISION

Original Filed May 29, 1929 3 Sheets-Sheet 1

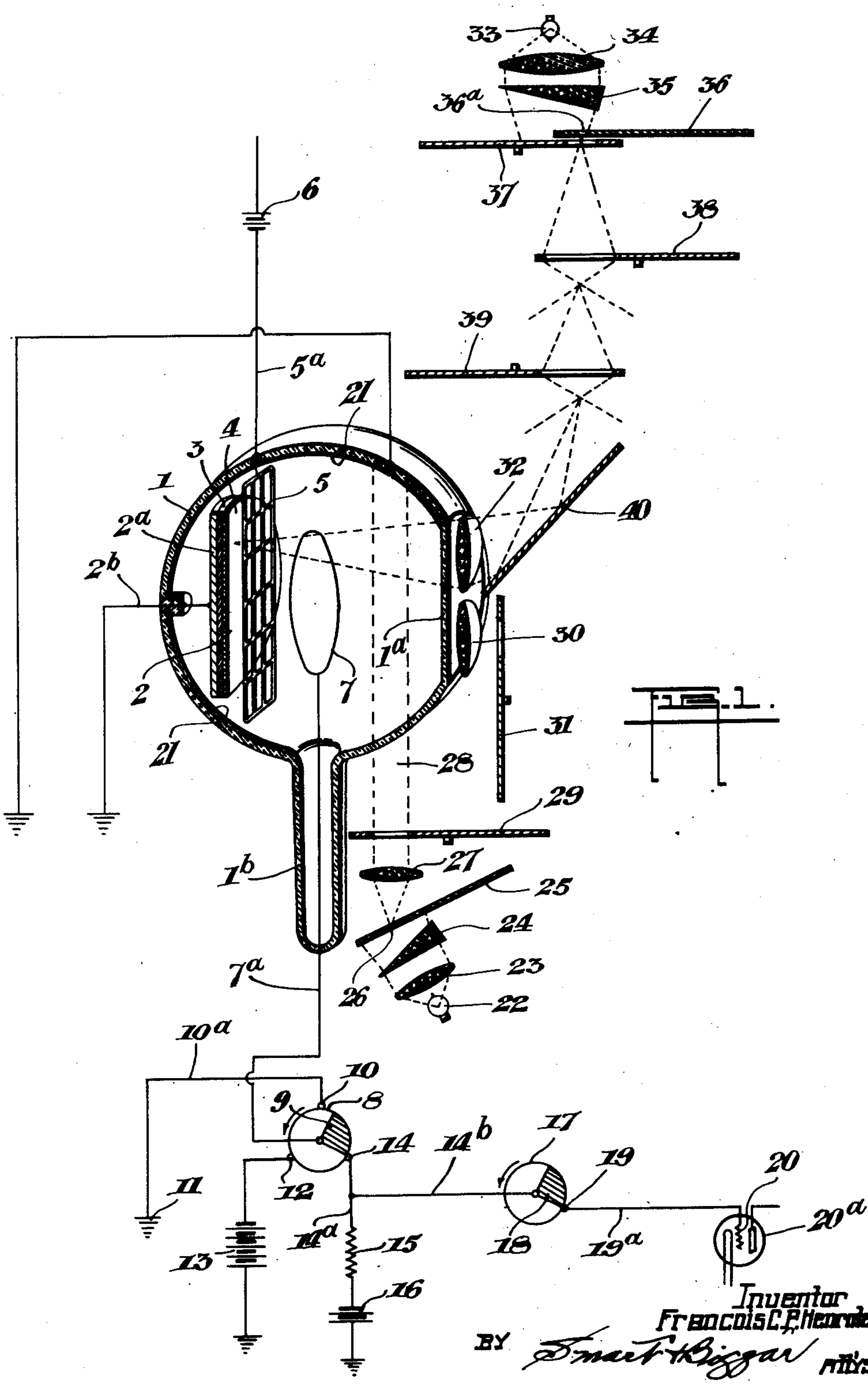

Fig. 1.

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TELEVISION

Original Filed May 29, 1929 3 Sheets-Sheet 2

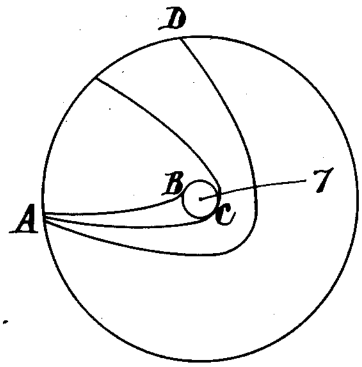

FIG. 2.

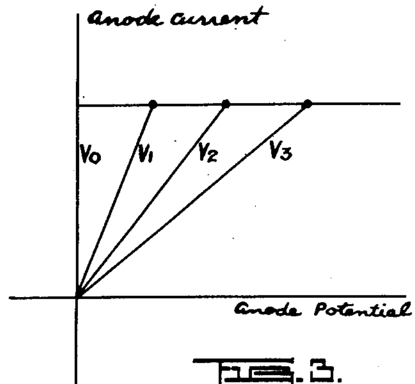

FIG. 3.

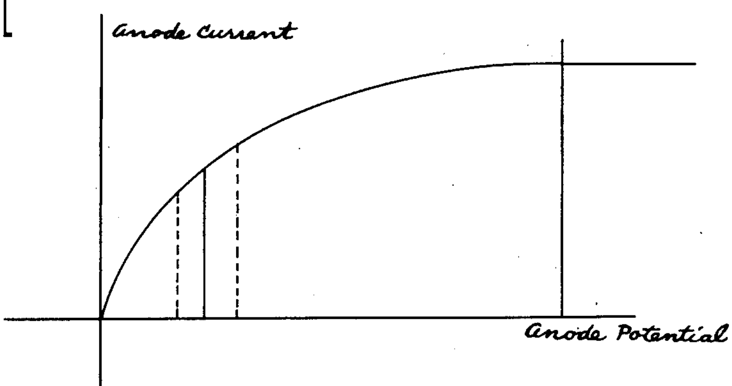

FIG. 4.

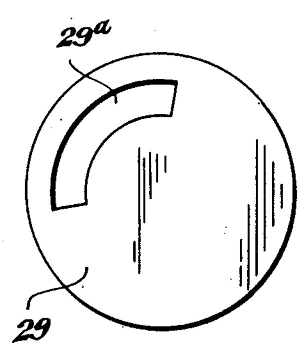

FIG. 5.

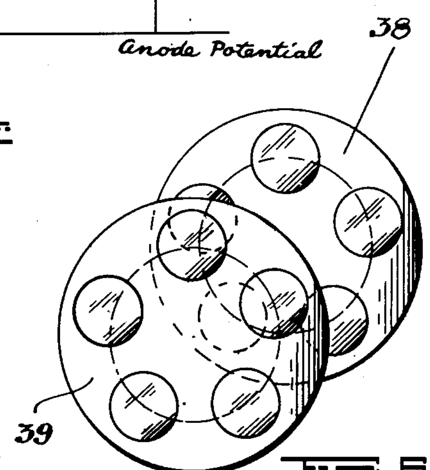

FIG. 6.

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TELEVISION

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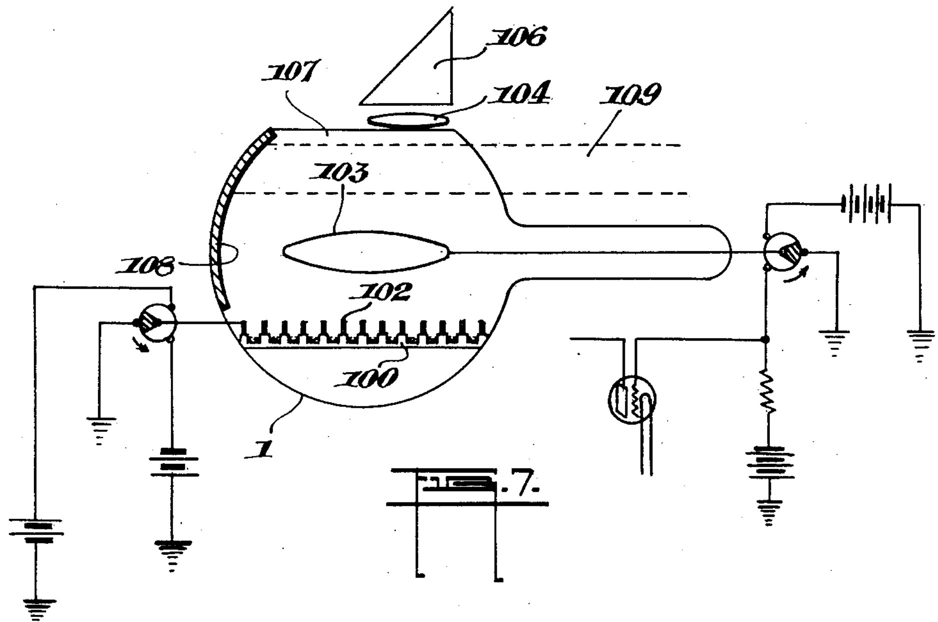

Fig. 7.

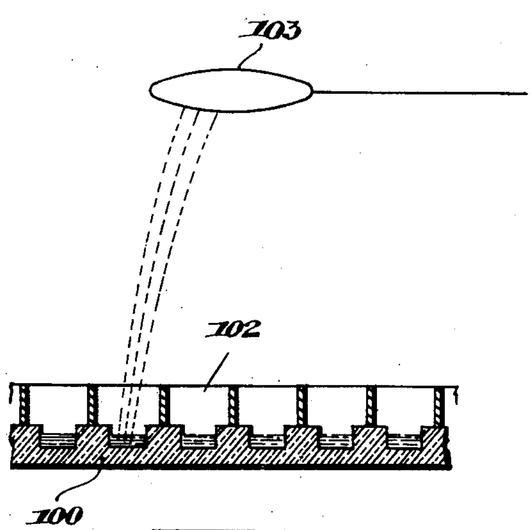

Fig. 8.

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Attys.

Patented Mar. 28, 1933 **1,903,112**

UNITED STATES PATENT OFFICE

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TELEVISION

Application filed May 29, 1929, Serial No. 367,084. Renewed August 13, 1931.

This invention relates to television, one object being to transmit either by wire or by radio the moving images of scenes under ordinary illumination and at the same time provide that the image transmitted be exceedingly sharp and well defined, showing even the smallest detail.

A further object is to permit the transmission of views covering large areas without artificial illumination.

Another object is to intensify the effect of a light image upon a photoelectric surface thereby to enable the photoelectric values to be more effectively impressed on a transmitting medium.

A further object is generally to simplify the steps of the method and the apparatus employed, to enable the various functions to be more effectively performed, and the invention consists essentially of the improved method and apparatus hereinafter described in the accompanying specification and drawings.

This application is a continuation in part of my previous application, Serial No. 298,-809, filed August 10, 1928.

In the drawings:

Fig. 1 is a sectional perspective and diagrammatic view illustrating the apparatus employed and showing certain of the electrical connections.

Fig. 2 is a sketch illustrating the photoelectric action and showing various orbits which may be described inside the photoelectric cell by the electrons.

Figure 3 is a diagram showing the different types of theoretical sensitivity curves found for high vacuum photoelectric cells when the saturation electronic current is the same but the electrons are emitted from the cathode at various constant velocities, v_0, v_1, v_2, v_3, corresponding to light of different wave lengths striking this cathode. In this figure the ordinates represent anode current and the abscissæ anode potential.

Figure 4 is a diagram showing the type of sensitivity curve usually found for high vacuum photoelectric cells when the cathode is struck by white light. The curve shown is, in effect, the resultant of the different curves shown in Figure 3 since white light is composed of light of various wave lengths. In this figure, as in Figure 3, the ordinates represent anode current and the abscissæ anode potential.

Fig. 5 is a plan view of a form of disc which may be used to interrupt either the view of the scene, the scanning or the strong beam of light used to bring the receiving screen nearly to zero potential.

Fig. 6 is a plan view of the two orthogonal scanning lens discs.

Fig. 7 shows a schematic view showing alternative forms of photoelectric cells.

Fig. 8 is a sectional and detailed view of the cathode used in the form of photoelectric cell shown in Fig. 7.

In the drawings, like characters of references indicate corresponding parts in all the figures.

Before proceeding to the description of the mechanism of this invention, it is necessary to explain how an ordinary alkali metal high vacuum cell operates when light falls on the cathode.

Referring to the drawings:

If a point A of the cathode 2 of a photoelectric cell (see Fig. 2) is struck by light, electrons are emitted in all directions with various velocities of expulsion. Considering a single electron it will describe an orbit which is determined by the direction of emission, the velocity of expulsion, the attraction of the anode 7 and the attraction or repulsion of the cathode. Some orbits will be like A B, the electron reaching the anode squarely, some like A C tangent to the anode, and some like A D, the electron never reaching the anode but falling back on the cathode at D.

The greater the potential of the anode, the more electrons emitted by the cathode it will attract to itself, and for a sufficiently high potential the anode will attract all the electrons emitted. This potential is called the potential of saturation, for if the potential of the anode is still increased the electronic current reaching this anode will remain the same.

An important fact of which I have taken

advantage in the present invention is that if the velocity with which the electron is expelled from the cathode is zero, this electron will move directly to the anode along a line of force of the electric field.

The different curves of Fig. 3 represent the variation of electronic current reaching the anode for various velocities of expulsion of electrons from the cathode, when the potential of the anode increases. These curves are nearly straight lines of various inclinations until the saturation current is attained.

Another important fact is that the maximum velocity with which the electrons are expelled will be different for lights of different colours which strike the cathode. The nearer the violet, the greater the velocity, and for a certain colour nearer the red the velocity of expulsion will be zero.

Theoretically the law of photoelectric activity expressing the maximum kinetic energy that can be imparted to an electron leaving a photoelectric material under the influence of light is expressed by the formula

$$\frac{1}{2}mv^2 = h(\nu - \nu_0)$$

where v is the velocity of expulsion of the electron, m its mass, h is Planck's universal constant and equal to $6.55 \times 10-27$ erg. sec., ν is the frequency of the light striking the photoelectric material, and $h\nu_0$, also written w_0, is a constant called the electron affinity, varying with the nature of the photoelectric metal; it is the minimum energy necessary to tear off an electron from the atom of this metal.

From the above formula it can be seen that when $\nu = \nu_0$ the maximum velocity of expulsion of the electron is zero; that is for light of that particular wave-length or colour a number of electrons become just barely detached from their atom. When ν is smaller than ν_0 there is no emission of electrons and when ν is somewhat larger there is emission of some electrons with a very small velocity of expulsion.

For potassium the colour for which $\nu = \nu_0$ is somewhere in the green region. In the violet, the velocity of expulsion has a fairly large value. Light near the particular colour for which $\nu = \nu_0$ is used is my invention, as will be seen in its mechanisms. The law of photoelectric activity to which I have referred is fully discussed in any of the following works, to which reference may be had: Dictionary of Applied Physics, by Richard Glazebrook, Vol. II, page 594; Photo-Electricity, by H. Stanley Allen, page 142; The Voltage Current Relation in Central Anode Photoelectric Cells, by H. E. Ives and T. C. Fry; Astrophysical Journal, 1922, vol. 56, page 1.

Proceeding to the description of the various parts of the apparatus:

In Fig. 1, 1 indicates a suitable photoelectric cell in the form of a vitreous or glass container exhausted to a high degree of vacuum in the manner known in the art; 2 indicates the cathode located at the back part of the container or cell formed of a large number of insulated photoelectric elements. For instance it may comprise a metallic plate 2*a* grounded through a suitable conductor 2*b* which passes through the wall of the container and is suitably sealed therein. Upon the plate 2*a* is placed a layer of some insulating material 3 such as aluminum or magnesium oxide. Upon this is placed a layer 4 of potassium or other photoelectric material, subdivided into tiny elements insulated one from the other. These insulated elements could be groups of pure potassium globules formed in a layer of insulating potassium hydride.

The photoelectric material, such as potassium, is evaporated on the aluminum oxide, or other insulating medium and treated so as to form a colloidal deposit of potassium hydride containing minute globules of potassium. Such a coating of photoelectric material has been prepared before by V. K. Zworykin (see United States Patent No. 1,691,324, Nov. 13, 1928, page 2, lines 1 to 9). The globules are really insulated one from the other and each of them constitutes so to speak a minute and very active photoelectric cell. Moreover, in this case, each globule backed by the plate 2*a* and the insulating material 3, forms a tiny condenser, the electrical capacity of which should be such that it acquires a certain positive potential under the action of the light received from the scene to be televised. For example, the tiny condenser might acquire a potential varying between zero and twenty volts according to the amount of light received.

The surface 4 might also be prepared by bombarding with cathode rays a very thin layer of potassium hydride; these rays having passed through a very fine sieve transform elementary areas of the screen into groups of fine globules of pure potassium. Also, sodium, cæsium, or rubidium hydride might be used.

The portion of the photoelectric cell 1*a* opposite the cathode 2 constitutes a window and may be formed with a relatively plane surface through which light may be projected by the lenses 30 and 32, which lenses will be suitably mounted in relation to the photoelectric cell with the usual provision for adjusting or focusing. The surface 4 should be arranged to coincide with the focal plane of the lens 30, which lens of course could be moved back and forth in order to focus all pictures or scenes at various distances in front of the apparatus.

The grid 5 which is positioned between the cathode and the anode consists of large squares of thin wire; it is kept charged at a low potential, for instance, at two or three volts by a battery 6 connected to the grid by conductor 5*a* which extends through and is sealed in the walls of the photoelectric cell. 7 indicates the anode which is located within the cell at about the centre thereof, and is in the form of a wire loop arranged in a plane parallel to the cathode element 2 and connected to a conducting wire 7*a* which extends outwardly through the extension 1*b* of the cell, and is sealed therein.

Provision is made for making various electrical connections to the anode, this being accomplished by rotatable commutating elements 8 and 17 driven at a suitable speed as hereinafter described.

The commutator or wheel 8 is of insulating material and formed with a metallic sector 9 to which the conductor 7*a* is connected, the angle at the centre of this metallic sector being a little less than 120°. Suitable contacts 10, 12 and 14 are arranged about the commutator 8, 120° apart from each other, the contact 10 being connected to ground 11 through the conductor 10*a* while the contact 12 is connected to the positive pole of a high voltage battery 13, the potential of this pole being, for instance, 500 volts; and the contact 14 is connected by conductor 14*a* through a resistance 15, to the positive pole of the battery 16, the potential of this pole being, say, 100 volts. Both the batteries 13 and 16 are grounded.

The contact 14 is also connected by means of a conductor 14*b* to a commutator 17 which is to be rotated at the same speed as the commutator 8 and is formed of insulating material with a metallic sector 18 having an angle at the centre slightly smaller than that of the sector 9. The arrangement may be such that the sector 9 connects with the contact 14, slightly before the sector 18 connects with the contact 19 thus permitting the high charge on the anode to be absorbed by the battery 16 before the connection with the contact 19 is made. The contact 19 is connected by conductor 19*a* to the grid 20 of the first thermionic valve or tube 20*a* of a suitable thermionic valve or vacuum tube amplifier, the electrical connection and arrangement of which are now well known in the art.

The interior of a large part of the photoelectric cell 1 is coated with a coating 21 of photoelectric material such as potassium. The coating is designed to be affected at intervals as hereinafter described by an energizing beam of light 28, this preferably passing through one side of the cell at a direction substantially parallel to the plane of the cathode so as not to strike the latter. This beam of light is interrupted at intervals and is of such light that the frequency of the colour is somewhat larger than the frequency w_0, for which electrons are merely detached from the photoelectric material. The electrons emitted have then a very small velocity of expulsion and if all the objects inside the cell are at zero potential except the grid 5, then all these electrons will be captured by the grid.

The drawings illustrate a convenient method of producing this beam of light from a very strong source of light 22, such as an arc lamp or a pointolite lamp of high candle power. This light, after passing through lens 23 and prism 24, forms a spectrum in the plane of the screen 25 which has a narrow aperture or slit 26 which allows light of the desired wave length to pass, which light after passing through the lens 27 forms the beam 28 which strikes the interior of the photoelectric cell.

Other known methods of obtaining a coloured beam such as the use of a coloured screen of Iena glass might be used if necessary. Also, if necessary to increase the intensity of the beam, a bank of several lamps 22 might be used.

To interrupt the beam 28 at intervals, a rotating disc 29 is provided, the form of which may be as shown in Fig. 5, the disc being formed with a segmental aperture 29*a* covering an arc of somewhat less than 120°. This disc is rotated very rapidly and at each revolution the aperture is designed to permit the beam of light to strike the surface of the photoelectric cell for approximately 1/50 of a second.

The image of the view to be televised is formed on the cathode by any convenient lens system. I have illustrated lens 30 designed to form such an image. Associated with this lens is means for interrupting the light which forms the image, this interruption being conveniently accomplished by a rotating disc 31 of similar form to the disc 29 and rotating with the same speed.

Means are also provided for scanning the surface 4 with extreme rapidity. The means which I provide for the purpose include a lens 32 which allows a spot of light to scan the surface 4. While various known methods of scanning may be used with other parts of the apparatus herein described, the following scanning means will be found to possess special utility.

This scanning means include a suitable concentrated source of light 33 such as a bright pointolite or arc lamp having brightness as great as 1,000 candle power. Where it is desired to use light of a short wavelength, the arrangement described with respect to the reduction of the beam 28 may be used, such a short wave length being of advantage in order to obtain a large velocity of expulsion for the electrons emitted by the plate 4. In this way a curve of electronic current similar to v_3 of Fig. 3 can be obtained for various potentials of the anode 7.

Assuming, therefore, that it is desired to produce light of a certain colour, there is provided for this purpose a lens 34 suitably arranged with respect to the light source 33 and designed to project a beam through a prism 35 from the spectrum of which the light of the desired colour will be selected by a screen 36 having a suitable aperture 36*a* therein. The light passing through the aperture 36*a* is interrupted by a rotating disc 37 similar in form to the disc 29 and rotating at the same speed. The three discs 29, 31 and 37 are all rotated at the same speed and are so arranged with respect to each other that they allow the respective beams of light, which they control, to pass one after the other. For instance, the light coming from the disc 29 will pass 1/50 of a second; then the beam from the disc 31 will pass also 1/50 of a second; finally, the beam from the disc 37 will pass for 1/50 of a second. The beam from the disc 37 also passes through certain lenses inserted in the two rotating discs 38 and 39 which are arranged one above the other and in overlapping relation, as indicated in Fig. 6.

Each disc carries a plurality of lenses and they are so arranged with respect to each other that when a lens of one is superimposed on a lens of the other, the respective directions of motion are at right angles when they cross each other. The disc 38 is rotated rather slowly while the disc 39 is rotated at a much higher speed.

The discs are so placed and the focal lengths are so computed that the real image of the point of light from the light source 33 is formed on the plate 4.

Care should also be taken that the beam of light coming from any lense of either of the discs 38 or 39 form a cone of much wider angle than the cone formed by the beams of light entering these lenses or entering the lens 32. This is to ensure that the point of light, which is the image of light source 33, remains constant in brightness as it is impelled to scan the plate 4 by the rotation of the two discs.

By modifying the focal length of the lens, and increasing the brightness of the light source 33, the scanning spot of the plate 4 may be rendered extremely small and intensely bright; moreover, the successive lines of the scanning on this screen will be exceedingly close to each other in proportion to the speed of the disc 39 with respect to that of the disc 38.

All of the various discs may be conveniently driven from a single source of power such as a motor, the discs 29, 31, 37 and commutators 8 and 17 having the same speed of rotation.

In order to permit the scanning arrangement and light filtering device associated with the light source 33 to be arranged in a vertical direction above the photoelectric cell, it may be convenient to use a mirror 40 which deflects the light coming from the disc 39 through the lens 32.

Having thus described the various parts of this invention, the working method of the system is as follows:

To begin, no light enters lens 30 or lens 32, and anode 7 is grounded, while the sector 9 comes in contact with contact 10. Then occurs a rapid succession of operations:

(*a*) While anode 7 is connected to ground 11, for the small fraction of a second an extremely strong and wide beam of light 28 passes through the opening in disc 29 and strikes the photoelectric surface 21. The colour of this light corresponds to a frequency slightly larger than ν_0, as explained above. The surface 21 under this treatment will emit electrons, which, on account of their extremely small velocity of expulsion will all be attracted by the grid 5. If, however, any of the potassium globules of surface 4 are at a higher positive potential than grid 5, they will attract some of the electrons and drop to a potential very nearly the same as that of grid 5. If the potential of grid 5 is about +2 volts, the potential of the various globules will become very nearly +2 volts, some, perhaps, being at a trifle lower potential and some at a trifle higher potential. It may be said that the potential of surface 4 drops practically to a uniform value.

As a matter of fact the presence of a grid 5 is not necessary, as surface 4 alone might absorb some of the slow moving electrons until all the globules will acquire very nearly the same small negative potential; beyond this value of the negative potential the globules will absorb no more electrons and the electrons emitted will either fall back on 21 or remain in the cell to be absorbed rapidly by anode 7 as soon as this anode becomes highly charged. The grid 5 may therefore very well be omitted in the apparatus shown in Fig. 1.

(*b*) The beam of light 28 is interrupted, anode 7 comes into connection with the high battery 13 and for the fraction of a second the opening in the disc 31 allows the image of the scene to be formed on surface 4. The photoelectric globules which receive more light will send out more electrons on anode 7, and consequently will become charged more positively than the globules which receive less light. All the electrons will be absorbed by anode 7 on account of the high potential of the latter. The positive charges accumulating in the small condensers formed at the back of the globules or in the globules themselves might vary from nearly zero to nearly twenty volts according to the amount of light received.

(*c*) Immediately after lens 30 is closed, the disc 37 allows the scanning beam to enter through the lens 32. Preferably, the light of this beam should be of short wave-length to give greater initial velocities to the electrons it liberates, but it could also be ordinary white light. Naturally monochromatic light would also present advantages because the various lenses which must be traversed need not be achromatic.

When the scanning spot passes over globules of higher positive potential, the electrons which these globules expel will start moving with an initial velocity, equal to the velocity given to them by the quanta of light minus the pull of the positive potential of the globules. The perturbing effect of the positive charge of the anode upon the moving electrons will be greater when the globules from which they come are at a higher positive potential and, consequently, more electrons will reach anode 7 than when the original globules are at a lower positive potential.

During this third operation (*c*) only, anode 7 is connected to the grid 20 of the first thermionic valve of an amplifier which is the first step in reproduction of the image by known methods.

Evidently the reproduced image will be a negative of the scene, but in the process of amplifying it is easy to transform it again into a positive.

Immediately after lens 32 is closed, the series of operations (*a*), (*b*), (*c*) is repeated again many times. Every time operation (*a*) brings all the photoelectric globules to nearly the same small potential.

To be explicit, if operation (*a*) lasts 1/50 second (*b*) 1/50 second and (*c*) 1/50 second, the image produced on the receiving screen will apparently be a non-interrupted moving picture.

Also, if a cell similar to 1 is used, but in which disc 30 rotates more slowly, very faint images of still objects formed on surface 4 could be transmitted to a nearly receiver which would give a very strong, enlarged, and contrasted image of the object, owing to electric amplification. The instrument could be attached to a powerful astronomical telescope and while the image focussed on the screen 4 would be large and weak, a very vivid strong image would appear in the receiver, by having a scanning mechanism geared to the scranning of the transmitter in order to eliminate difficulties of synchronization. The cell could also be attached to a microscope and permit the study of objects hitherto impossible to see.

In Figs. 7 and 8 I have shown an alternative form of my invention.

Referring to these figures, 100 indicates the cathode or receiving screen which is composed of a large number of photoelectric elements insulated one from another and conveniently made from a glass plate and having a large number of small cups, each filled with a liquid photoelectric metal such as the well known alloy of potassium and sodium, the cathode in use being arranged in a horizontal position. 102 indicates the grid formed, for example, of a solid metal plate through which a large number of holes have been bored. These holes should be placed opposite to the cups containing the potassium sodium alloy in the cathode 100.

In construction it may be found convenient to have the grid 102 touching the glass plate 100, making certain, however, that no contact is established with the photoelectric material filling cups. In this way electrons emitted from one cup cannot easily go to another cup. 103 indicates the usual anode connected as already described. 104 indicates the lens designed to form an image of the scene on the cathode; 106 is a reflecting prism by which a view seen in a horizontal direction may be reflected through the lens 104. The beam of light from the lens 104 passes through the window 107 of the photoelectric cell. The photoelectric cell will be coated on the inside with photoelectric material 108.

The operation of this form of the invention is substantially as follows:

To begin with, no light enters through the lens 104 or through the window 107. The grid 102 and anode 103 are grounded. Then occurs a rapid succession of operations:

(*a*) While the grid 102 and anode 103 are grounded, a strong beam of nearly monochromatic light 109 is projected on the photoelectric material 108. The colour of the light is such that it produces only the ejection of slow moving electrons from the material 108, these electrons bringing the various metallic elements of the plate 100 to zero or nearly zero potential.

(*b*) The beam 109 is interrupted, the grid 102 is connected to an appropriate source of positive potential, and the image of the scene coming in through the lens 104 is allowed to form on the cathode 100. The elements of the cathode 100, which receive more light, send more electrons on the grid 102 and thus acquire a charge which is more highly positive.

(*c*) The light from the scene is interrupted and a very strong scanning beam of light enters through the window 107. At the same time the grid 102 is connected to a source of negative potential such that it will stop all the electrons coming from an element of the cathode 100 if this element is at a certain potential and let them pass in increasingly greater quantity as the potential of this element decreases. At the same time also the anode 103 is connected to a source of potential high enough to absorb all the electrons which, under the influence of the scanning beam, have passed beyond the grid 102. Thus the scanning beam acting in succession upon every photoelectric element of the cathode 100 sends electrons on the anode 103 in a number which is an inverse function of the potential of the emitting photoelectric element. An element of the cathode 100, the part of the grid 102 opposing it, and the anode 103 in this case really constitute a kind of three electrode valve in which, what corresponds to filament temperature, is the amount of light received by the photoelectric element of the cathode 100.

The anode 103 during this operation, besides being connected to the source of potential as above, is also connected to a suitable amplifying and transmitting apparatus. The electronic impulse received by the anode 103, being amplified and transmitted, will cause the image of the scene to be reproduced on any receiving screen which is scanned by a modulated beam of light synchronously with the scanning of the cathode 100.

(*d*) The lens 104 and window 107 are closed and the succession of operations, (*a*), (*b*) and (*c*) is repeated again and again. If this repetition is performed fast enough, the image on the receiving screen will appear as a moving image of the object.

If it is supposed that the receiving screen or cathode of the cell has been divided into 10,000 insulated elements (100×100) the time that the scanning beam will act upon one element will be 10,000 times shorter than the time that the light of the scene acts upon the same element. However, the light received by the element from the scanning beam can be made, on the average, 10,000 times greater than the light received from the scene. The electric energy liberated from one element of the photoelectric cathode by the scanning beam will thus be of the same order of magnitude as the energy liberated by the light of the scene which strikes that element, because in both cases the energy liberated is proportional to the intensity of the light received multiplied by the length of time that the light is acting. The energy which is going to be utilized for the transmission of the scene's picture is thus 10,000 times greater than if the scene itself had been divided into 10,000 elements and each of these elements transmitted one after the other, as has been done up to the present in all known methods of television. It is thus as if the scene was 10,000 times brighter and it can be understood that no matter in how many elements the cathode is subdivided, whether it be 1,000,000 (1000×1000) or 100,000,000 (10,000×10,000) provided the brightness of the scanning beam is increased accordingly, the picture will be transmitted with equal strength, using the same amplifier. Daylight television is thus possible and with a great wealth of detail if the number of insulated elements of the cathode is large.

What I claim as my invention is:

1. Television apparatus comprising a photoelectric cell having therein only an anode and a cathode with a photo-sensitive surface, means for projecting an image of a view on said cathode, means for interrupting the projecting of said image, means for thereafter scanning said cathode by a beam of light to cause the photosensitive surface of the latter to emit electrons and means for causing said anode to absorb a number of electrons, said member varying solely by reason of the potential of the elements from which the electrons were emitted.

2. The method of television which comprises projecting an image of a view on a photosensitive screen to raise elements of said screen to varying positive potentials, interrupting the projection of said image, then scanning said screen with a beam of light to cause the elements thereof to emit electrons and causing an anode associated with said screen to absorb a number of electrons, the passage of electrons from said screen to said anode being unopposed and the number of electrons absorbed by the anode varying solely by reason of the potential of the elements from which these electrons were emitted.

3. The method of television which comprises projecting the image of a view on a photosensitive screen to raise elements of said screen to varying positive potentials, causing a beam of light to scan said screen to cause the elements thereof to emit electrons, causing an anode associated with said screen to absorb a number of electrons, the passage of electrons from said screen to said anode being unopposed and the number of electrons absorbed by the anode varying solely by reason of the potential of the elements from which these electrons were emitted, and indirectly restoring the elements of the photosensitive screen to a uniform potential by projecting a beam of light on a photosensitive surface other than the screen.

4. The method as claimed in claim 3, in which the scanning beam of light is coloured.

5. The method as claimed in claim 3, in which the second mentioned beam of light is coloured.

6. The method as claimed in claim 3, in which both the scanning beam and the second mentioned beam of light are coloured.

In witness whereof I have hereunto set my hand.

FRANÇOIS CHARLES PIERRE HENROTEAU.