JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 4258 — FRIDAY, JUNE 29th, 1934 — VOL. LXXXII

All Communications for the Society should be addressed to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2. (Tel. Temple Bar, 8274).

PROCEEDINGS OF THE SOCIETY

TWENTY-FIRST ORDINARY MEETING

WEDNESDAY, MAY 2ND, 1934

JOHN LOGIE BAIRD, Managing Director, Baird Television, Ltd., in the Chair

The following paper was read :—

TRICHROMATIC REPRODUCTION IN TELEVISION

By J. C. WILSON

(of the Baird Laboratories)

The following paper deals with the problem of transmission of television pictures in natural colours, and comprises a description of the Baird process, with which the author has been principally engaged.

In *Part A* there are described the circuits and apparatus used during the first demonstration of colour television, together with details of the results obtained and an indication of the difficulties still to be overcome.

In *Part B* there is a short exposition of the theoretical principles underlying the three-colour process.

PART A

(1) INTRODUCTORY

The problem of transmitting television images in colours is not a new one. Amongst the early investigators in this field the names of von Bronk[1] and Adamian[2] may be mentioned. But it is not until comparatively recently that results have been achieved. In 1928 J. L. Baird produced colour pictures over a short line circuit, using a single bank of gas-filled potassium photocells, and demonstrated his results at the meeting of the British Association held in Glasgow that year. A little later, Dr. Ives, working in the Bell Laboratories in America, produced coloured television images using a composite bank of photocells of differential colour sensitivity, with a system of correspondingly increased complexity.[3]

In addition to these, many other systems have been described, chiefly in the specifications of Letters Patent, but the nature of these schemes has been purely theoretical; the present system is the only one developed for use. Both Baird and Ives used mechanical scanning and reconstituting devices, and in contradistinction to these may be mentioned the proposals of Ardenne,[4] Zworykin[5] and Siemens & Halske A.G.,[6] to employ cathode-ray reconstitution, while of those employing mechanical methods, the suggestions of Hammond,[7] Ahronheim,[8] and the British Thomson-Houston Co.[9] are of interest. In some of these systems a colour-mosaic screen is interposed in the path of the scanning-beam at some suitable point, or, alternatively, adjacent lines of the traverse are differently coloured. In these types of system the fine-structure of the picture is not truly coloured, but the impression of coloured reproduction depends upon the inability of the eye to discriminate between a patchwork of primary colours in small discrete areas, and the hue which would be formed by, as it were, smearing them slightly. In others the coloured effect is obtained by carrying out a whole scan in one homogeneous, or effectively homogeneous, colour and then repeating the process within the period of retentivity of the eye in another colour, the quickly-repeated coloured impressions being superposed, of course, by the psychological effect of persistence of vision. In these processes two scanning colours may be used, one being complementary to the other, or more than two colours, in which case it is usual to choose three primary colours well separated in the spectrum, such as red, green and blue. The nature of the apparatus used to carry out a colour-television process naturally depends upon the method of scanning to be adopted, and we will proceed to examine an actual system, based upon the Baird light-spot method of scanning, in order to understand the modification necessary in order to transmit colours.

(2) Description of the Baird System

First of all, it is necessary to scan the scene an image of which is to be transmitted, and in the "light-spot" method this is accomplished by causing a spot of light to explore the whole scene cyclically in parallel strips, either vertically or horizontally, the strips lying closely adjacent to each other. Some of the light scattered back or diffused from the scene during this process is incident upon the sensitive surfaces of photo-electric cells suitably placed in front of the scene, in much the same positions as lamps would be if the scene were to be photographed by artificial light.[10]

Now the current through the photocells depends upon the amount of scattered

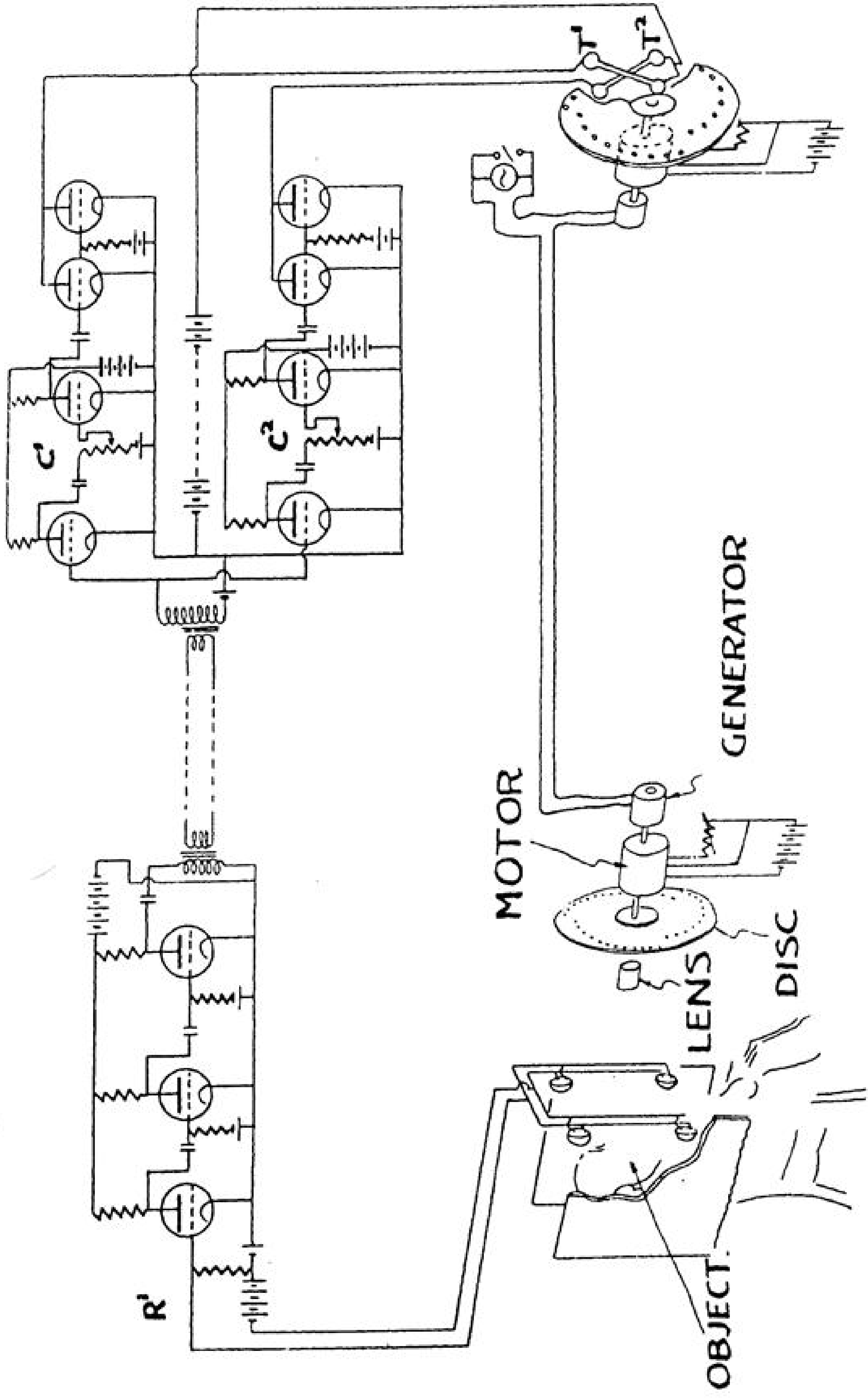

Fig. 1.

light falling on them, and this in turn depends upon the diffusivity of the portion of the scene instantaneously irradiated by the spot: thus the photocell current can, with suitable precautions, be made a faithful electrical representation of the brightness or darkness of the surfaces of all the objects within the ambit of the area scanned, strip by strip. In the normal scanning process, of course, white light, or light to which the cells are particularly sensitive, is used to form the travelling spot; in certain cases, for example with guitar-players, where the stroboscopic effect of a brilliant scanning beam on the player's fingers produces acute psychological distress, invisible "light" in the infra-red or ultra-violet ranges of the spectrum can be used.

If, instead of white or heterochromatic light, we use coloured light from a narrow spectral region, or substantially monochromatic rays, we shall expect to find that the light is scattered copiously only from those parts of the scene which are the same colour as the light, or which contain that colour as a constituent; other portions will absorb much or most of the radiation falling on them and will appear dark or black in the television reproduction. It is upon this physical effect that a colour-television process depends. The scene is scanned first with a red spot, then with a green one, and finally with a blue one, the photocells generating meanwhile a signal proportional first to the light scattered back during the red traversal, then to that during the green and blue traversals. At the receiving station a red colour-filter is held in the path of the image-forming rays while the "red signal" is being received, a green one during receipt of the "green signal," and a blue one during that of the "blue signal"; since the traversals take place very rapidly, the effect of three superposed coloured transparencies is yielded to the observer, and the analogue of the three-colour process in photogravure will make plain how the appearance of a naturally tinted picture results. Of course, the naturalness of the colouring depends upon the technical excellence in the various steps in the transmission, but of this we shall have more to say later.

Fig. 1 shows a diagrammatic lay-out of the apparatus actually used in the first colour-television demonstrations in the Baird Laboratories.* At the transmitter, a scanning disc similar to the ordinary Nipkow disc, but having three part-spirals of apertures each occupying a third of the marginal portion of the disc, is used, and light passing through the apertures is focused by a lens on to the object, in front of which are also arranged a number of photo-electric cells of the potassium hydride in argon type. The photocells are connected by wires to the input of a three-stage resistance-capacity coupled valve amplifier; the output from this amplifier is taken through a high-ratio step-down transformer to minimise the attenuating effect of the capacity between the line-wires upon the higher frequencies in the television signal. At the other end of the line the secondary of a corresponding step-up transformer feeds the signal to the initial valves of two separate valve amplifiers, termed the "red" amplifier and the "green and blue" amplifier

* See also specifications of British Patents, Nos. 321389, 319307, and 322776 (J. L. Baird).

respectively; these are similar to the "initial" amplifier except that amplitude-controls, C^1 and C^2, are provided at the input to the second stage and the valves are capable of handling much larger signal voltages. The output stages of these two amplifiers comprise two large high-voltage valves of the T250 class, in parallel; in the common anode circuit of the "red" amplifier output valves there is

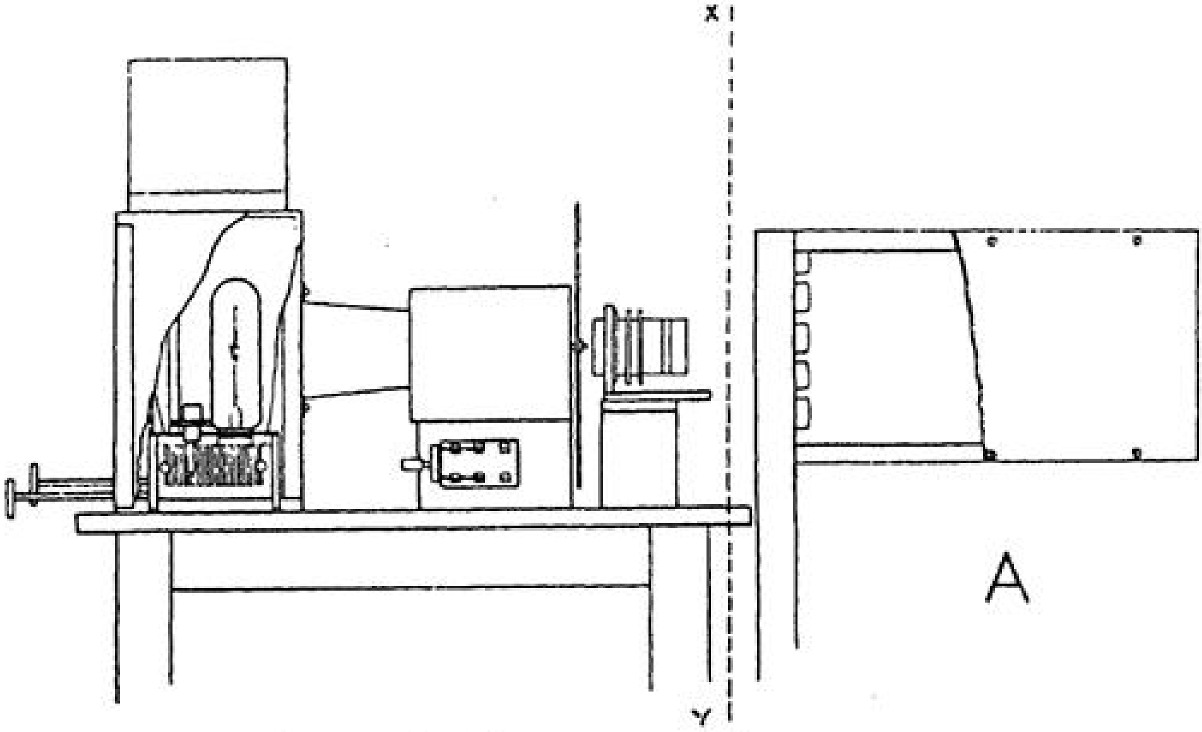

FIG. 2 (A).—ELEVATION OF TRANSMITTER.

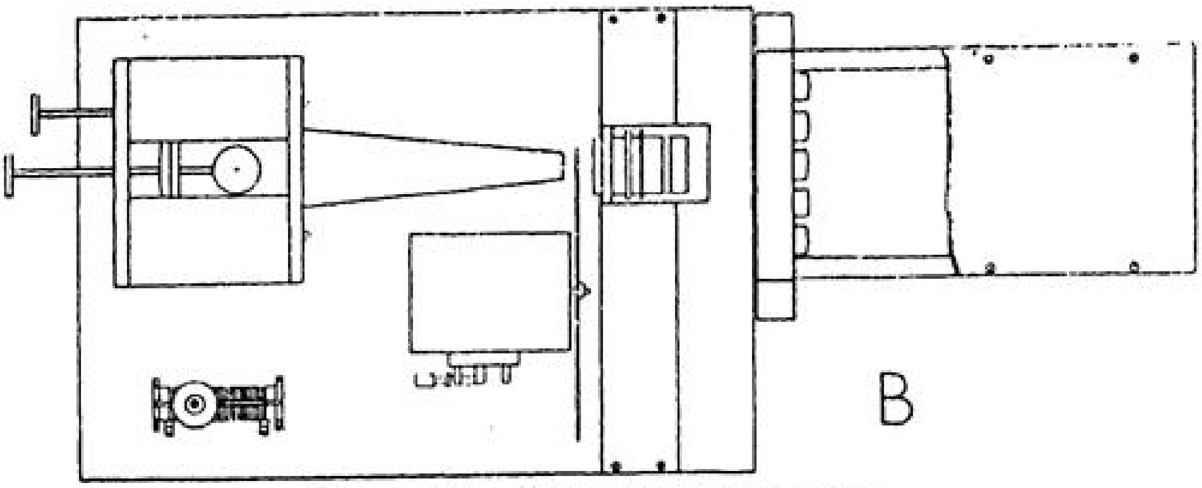

FIG. 2 (B).—PLAN OF TRANSMITTER.

connected a neon positive-column gas discharge tube, T^1, and in the other output circuit is connected a positive-column tube, T^2, filled with mercury vapour with a little helium. These tubes are crossed behind the viewing-area of the receiving scanning disc, which is geometrically similar to that at the transmitting end; in the original experiments, the discs each contained forty-five apertures, fifteen in each spiral segment, and the apertures in each segment were of such a size and so staggered, that they completely traversed the field of view. Motors, the speed of which could be regulated by variable resistances, were used to drive the discs at about 600 r.p.m., corresponding with a colour-cycle rate of 10 per second, and an image-speed of 30 per second. On the shaft of each motor there is coupled a small alternating-current generator, and these generators are coupled together by means of an additional line, with a small electric lamp in series at the receiving end : this lamp serves to indicate when the motors are in synchronism, and a short-circuiting switch allows them to be locked in step. This form of synchronising is not, of course, essential, since the two discs could be locked in phase by means of the picture-signal itself, and only one line would then be required ; it provides, however, a convenient laboratory method when automatic synchronism is not the subject of the experiment.

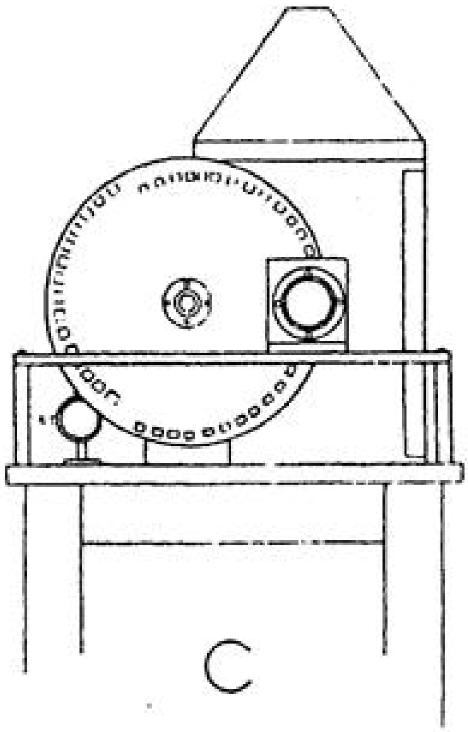

FIG. 2 (C) SHEWING VIEW ON XY IN FIG. 2 (A).

After the receiver is locked in step, the disc is phased, and the picture " framed," by rotating the carcase of the motor and generator together.

Fig. 2 shows additional constructional details of the transmitting apparatus: the projector-lantern for illuminating the marginal portion of the transmitting disc intensely can be seen.

The manner in which this apparatus functions will now, in the light of the previous discussion of colour-systems generally, have become clear ; the three series of scanning apertures in the discs are covered with red, green and blue gelatine colour-filters severally, so that, at the transmitter, the object or scene in front of the projector is traversed first with red light, then with green, and finally with blue, the cycle of operations being repetitive, and, at the receiver, the geometrically corresponding series of apertures are covered with similarly coloured

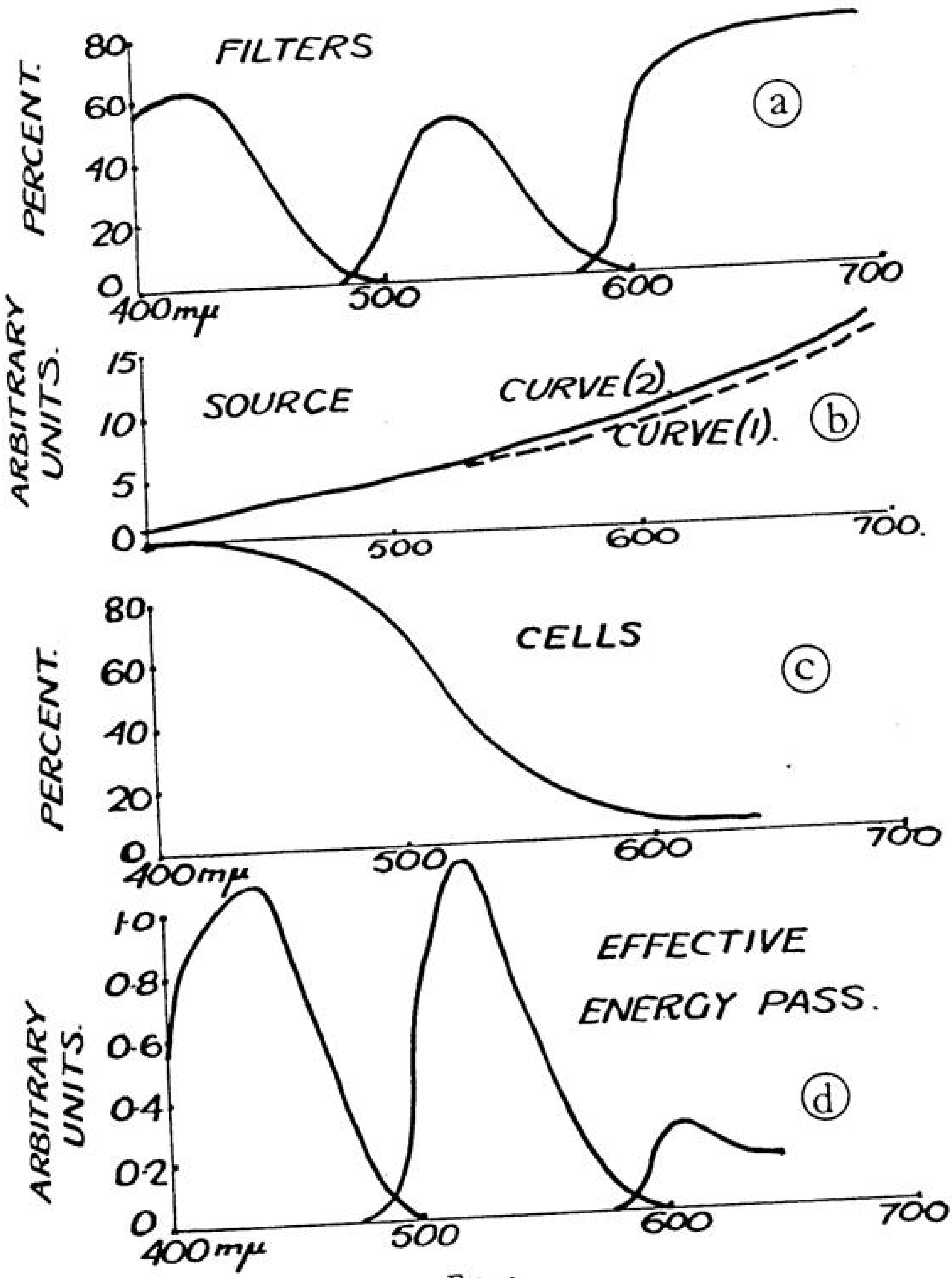
FILTERS
PERCENT.
80
60
40
20
0
400mμ
500
600
700
(a)
ARBITRARY UNITS.
SOURCE
CURVE (2).
CURVE (1).
15
10
5
0
500
600
700.
(b)
CELLS
PERCENT.
80
60
40
20
0
400mμ
500
600
700
(c)
EFFECTIVE ENERGY PASS.
ARBITRARY UNITS.
1·0
0·8
0·6
0·4
0·2
0
400mμ
500
600
700
(d)

FIG. 3.

filters. Then during the red traversal at the transmitter and the receipt of the "red signal" at the receiver both gas-discharge tubes are modulated in brightness in accordance with the instantaneous intensity of the signal, but only red light (principally from the neon tube) is allowed to reach the observer's eye, while during the blue and green traversals, and receipt of the "blue" and "green" signals, both tubes are again modulated, but it is only blue and green light from the blue and green spectral lines of the mercury-vapour tube that is allowed to pass through the holes of the receiving disc during the respective traverses.

We must now proceed to examine the system in greater detail, with some of the physical laws governing functioning of the components.

(3) Particular Description of Components

The light source used in the light-spot projector is a 900-watt bunched-filament gas-filled tungsten cine lamp having a working temperature of about 2,800° K. The filament bunch is about ¼" square and gives about 2,930 H.C.P.; using a spherical reflector 7·5" in diameter and 7·5" focal length, an image of the filament is focused upon the periphery of the Nipkow disc, the effective scanning area of which is 0·5" radially by 0·98" circumferentially. The image of the filament upon the disc is slightly more than 1" square, and with a coefficient of 0·7 for the spherical reflector, a flux of 3,314 lumens upon the disc is obtained, giving a flux per square inch of 2,920 lumens. The disc apertures are 0·033" square and the flux through each is 3·25 lumens.

An image of the picture area on the disc is brought to a focus substantially in the plane of the scene to be scanned by means of a lens of focal length 3·5" at aperture 1·5; the total transmission of this lens measured with reference to the spectrophoto-electric sensitivity of the potassium cells with tungsten radiation is 25·08 per cent.

Small pieces of colour filter are fastened to the scanning disc to cover each hole; the spectral transmission curves of these filters, which are similar to those used in tricolour photography, are shown in Fig. 3 a. We must notice, however, a most important difference between colour-television and colour-photography: the sensitive material of the photographic plate can be so chosen that it has a substantially even response to light of all colours, but the photo-electric materials are usually selectively responsive, and, further, have a more or less sharply defined "critical frequency." To light of wavelength corresponding to frequencies lower than this they are not sensitive at all, however intense the incident radiation; an equation, due to Einstein, expressing this in terms of quantum-mechanics is well-known: if w is the work necessary to liberate an electron from the sensitive material, and $mv^2/2$ is the kinetic energy possessed by the electron after liberation, we have

$$mv^2/2 + w = h.e$$

where e is the critical frequency and h is Planck's constant.

Ordinary potassium coatings, suitably sensitised, do not respond to light of wavelength longer than about 585 millimicrons, while monatomic potassium layers on silver, although having a lower critical frequency, are not sufficiently responsive to blue light; for use with incandescent tungsten, which is very deficient in blue rays, the high sensitivity of ordinary potassium cells to the blue is very desirable, and a mixture of the two forms of cell is necessary in practice. In this connection, it may be mentioned that sensitised barium cells of the type developed by T. W. Case, although they can be made to have a sensitivity-curve closely corresponding with that of the eye,[15] are not sufficiently responsive overall, and the method of sensitisation adopted by Olpin and Stilwell[16] is not satisfactory from the same point of view. A mixture of cells including some of the red-sensitive cæsium type, which seems to overcome the difficulty at first, fails owing to the fact that the colour-filters all have large infra-red passes in addition to those shown in the visible spectrum in Fig. 3 a, and the response of cæsium cells in this spectral region would mask the proper colour-differentiation of the filters.

The spectral emission of the incandescent tungsten filament is shown in Fig. 3 b: curve (1) refers to the light from the outside of the helical filament, and curve (2) refers to that from the inside. It will be seen that light from the inside appears to be at a higher colour-temperature§ than that from the outside; the value of this temperature is probably about 3,086°K.[17] but the effect cannot be due solely to higher temperature,[18] and is in all probability due to internal reflections within the coils of the helix. The light from within the filament is also highly polarised.

Fig. 3 c shows the relative response to the photocells used, over the visible spectrum, and Fig. 3 d gives the effective energy passes of the colour-filters (that is, the curves of Fig. 3 a modified in accordance with the emissivity and sensitivity curves of Figs. 3 b and 3 c). It will be seen that the response of the system in the yellow, orange and red is markedly lower than in the green and blue; instead of the term "effective lumens," which really has little meaning in view of the fact that a lumen is a measure of radiant energy evaluated by reference to the visual effect produced by it, let us take a "celumen" as the corresponding measure for photo-electric response: then the celumens passed in the scanning beam, the amount of scattered light caught by one cell of effective area 2·76 square inches situated 20″ from the object scanned, the photo-electric current for ten such cells in parallel, and the voltage developed across the resistance R^1 of Fig. 1 when the value of this resistance is 100,000 ohms, are set out in the following table:—

---

§ The wavelength of the centre of gravity of a spectral distribution is defined as:

$$\lambda_c = \frac{\int V.E.\ \lambda d\lambda}{\int V.E.\ d\lambda}$$

where λ = wavelength.
E = energy per unit λ for λ.
V = visibility of rays at λ.

Traverse.	Celumens :		Current for ten cells micro-amps.	Voltage across 100,000 ohms.
	(*a*) in beam.	(*b*) incident on cell.		
Red ..	0·021	$14{\cdot}9 \times 10^{-6}$	782×10^{-6}	78 microvolts.
Green ..	0·0909	64·5 ,,	3380 ,,	338 ,,
Blue ..	0·0952	68·6 ,,	3600 ,,	360 ,,

The effective flux in the beam is, of course, evaluated from the curves of Fig. 3 d by integration, knowing the response of the cells to full tungsten radiation, and the light actually incident on the cell has been calculated for object-surfaces of diffusivity 0·25 on the assumption that three-quarters of the diffused light is contained in a cone of semi-vertical angle 45° with its apex at the light-spot ; the validity of these assumptions will naturally depend upon the nature of the surface scanned, but for cutaneous surfaces they are probably not far out.

It is uneconomical as regards the full utilisation of the capabilities of the transmission channel to use markedly unequal signal-amplitudes during different-coloured traverses ; but, on the other hand, it is undesirable to cut down the effective "blue" and "green" signals by rendering the filters more opaque because the "red" signal, with the particular apparatus described, was not very far above the parasitic-and general-noise-level of the amplifiers. Compensation for inequality of amplitude of this kind can, of course, be readily obtained by adjustment at the receiver, but a preferable method, involving incidentally a desirable increase in "red" response, will be described later.

The Amplifiers

The amplifier system employed is extremely straightforward. The first three stages comprise valves of the DEL 610 class, having a magnification factor of 15, and an internal impedance of 7,500 ohms. With anode-resistances of 20,000 ohms, a dynamic magnification of about 11 per stage (the grid-resistances are high compared with 20,000 ohms) is obtained, and the overall magnification is about 1,300 times at medium frequencies. In this connection it must be remembered that a substantially flat frequency-characteristic from 10 cycles to about 13,500 cycles per second is desirable to accommodate the component frequencies of the television signal up to the "first zero-frequency" of the scanning-device used ; naturally, this range would be considerably extended in the case of a commercial colour-television system of proper resolving-power instead of the comparatively crude experimental apparatus described here to illustrate the principles, but in the case of a radio-transmission channel it is not necessary to go to the "zero-frequency."[19] Now although the phase-frequency and amplitude-frequency characteristics of resistance-coupled amplifiers can be made considerably better, especially at the lower frequencies, than those of transformer-coupled valves, it is necessary, even with moderate band-widths as in the present case, to take precautions against high-frequency attenuation. This attenuation is due primarily to small shunt capacities, such as the inherent capacity of the photo-cells, the working capacity of the grid-circuits of the valves, and the line-capacity; the working capacity of a triode, it should be remembered, is much higher than its static capacity: it is given by

$$C = C_{ga}(1 + m') + C_{gt}$$

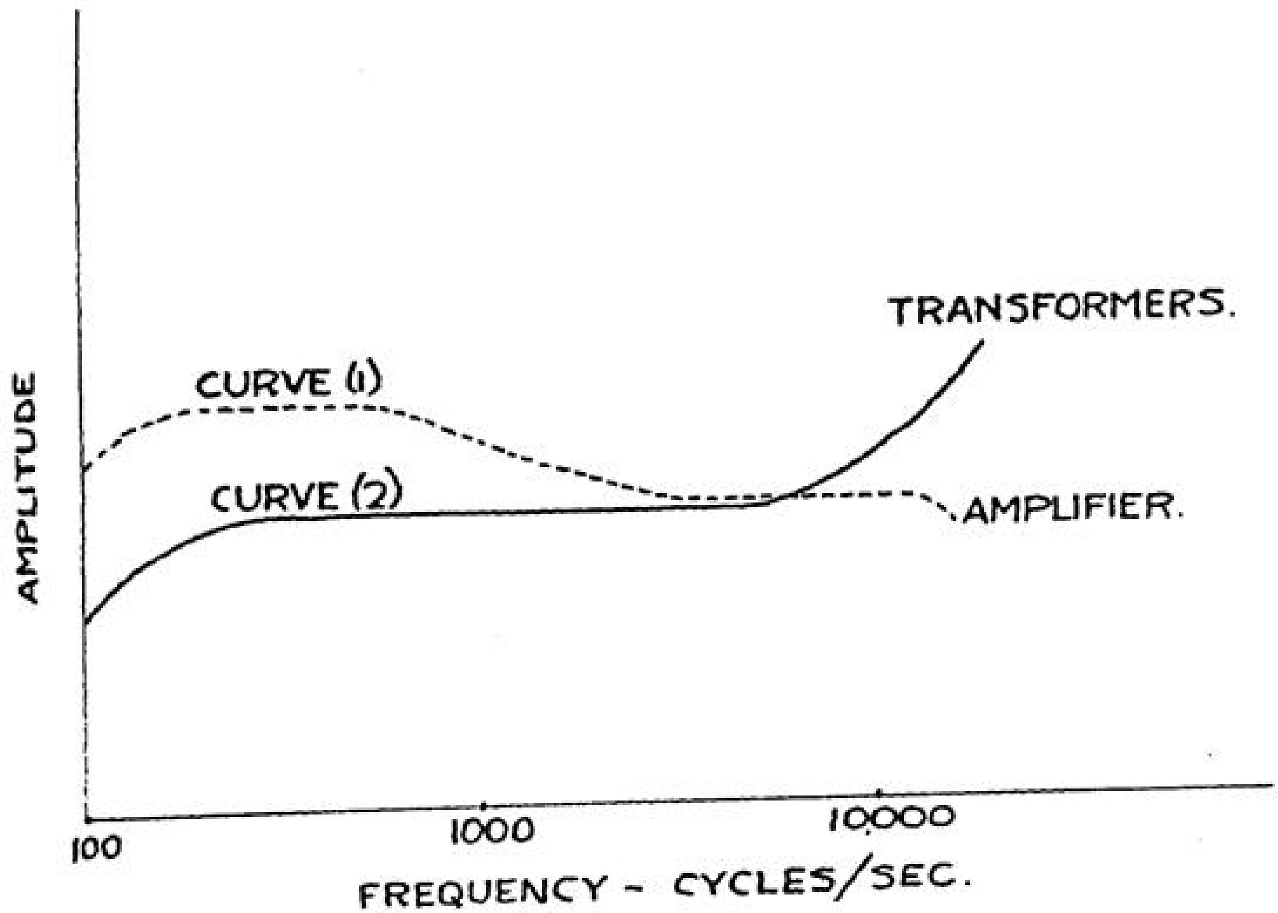

FIG. 4.

where:

C_{ga} is the grid-anode static capacity,
C_{gt} is the grid-cathode static capacity,
m' is the dynamic magnification of the stage.

It will thus be seen that it is advantageous to keep the anode-resistances low, in spite of a reduction in gain, in order to keep the total effect of this capacity small: for valves of the DEL 610 type, C_{ga} is 4·6 and C_{gt} is 4·4 micromicrofarads approximately, giving a grid-admittance of about 0·5 micromho. This is small, of course, compared with that of the anode-resistances used.

The second section of the amplifier comprises two series of three stages each in parallel; in each series the first valve is an LS 5 B, the second an LS 5, and the final either two T 250 valves in parallel, or, with an appropriately lower high-tension voltage, one DA 60. The amplification is arranged to bring the overall magnification of the system up to about 68 decibels.

The effect of the introduction of the line-transformers into the system is illustrated in Fig. 4: curve (1) is the overall response-curve of the amplifiers themselves, and curve (2) is the curve of the transformers and line alone. Low-frequency attenuation is, of course, marked.

The Receiver

At the receiver the source of light is not a radiator supplying a continuous spectrum with filters to transmit certain bands; the two gas-discharge tubes* emit a composite line-spectrum, from which, in the case of the blue and green traversals, the blue-violet and green lines of the mercury spectrum are isolated, and in the case of the red traversal, a bunch of red-orange lines, together with the fainter red mercury lines, are selected. The light-filters used do not need, therefore, to be entirely mutually exclusive. It is true that there is considerable energy radiated in the form of a continuous spectrum by mercury-vapour,[20] but in the green and blue this energy is small compared with that radiated at the characteristic wavelengths. The following table shows the principal wavelengths and relative intensities emitted by the two tubes in the visible spectrum :—

Colour.	Gas excited.	Wavelength.	Intensity radiated.	(Arbitrary Units) passed.
Blue ..	Mercury	365 millimicrons	—	Nil.
		398 ,,	—	Nil.
		405–8 ,,	0·8	Nil.
		436 ,,	1·3	0·12
Green ..	Mercury	546 ,,	2·6	1·56
		577–9 ,,	4·5	Nil.
Red ..	Neon	585 ,,	16·0	5·0
		607 ,,	48·0	28·8
		640 ,,	54·c	33·0

It will be seen from this that the neon radiation preponderates considerably, not only in number but in intensity of the effective spectral lines. This is due to the lack of infra-red emission from neon, nearly all the lines being within the

* See also specification of British Patent, No. 322823 (J. L. Baird).

visible spectrum. The total candles per watt of the mercury tube is about 0·4, while that of the neon is 1·6 approximately ; in order to obtain a proper colour-balance it is therefore necessary to cut down the mean current passing through the neon tube by adjustment of the negative bias upon the grid of the power-stage feeding it, and so to adjust the amplitude-controls C^1 and C^2 that the brightness variations of the two tubes correspond properly over the working range.

To increase the brilliance of the picture, a spherical reflector is placed behind the tubes, which are crossed behind the picture-area of the receiving disc. Colour-

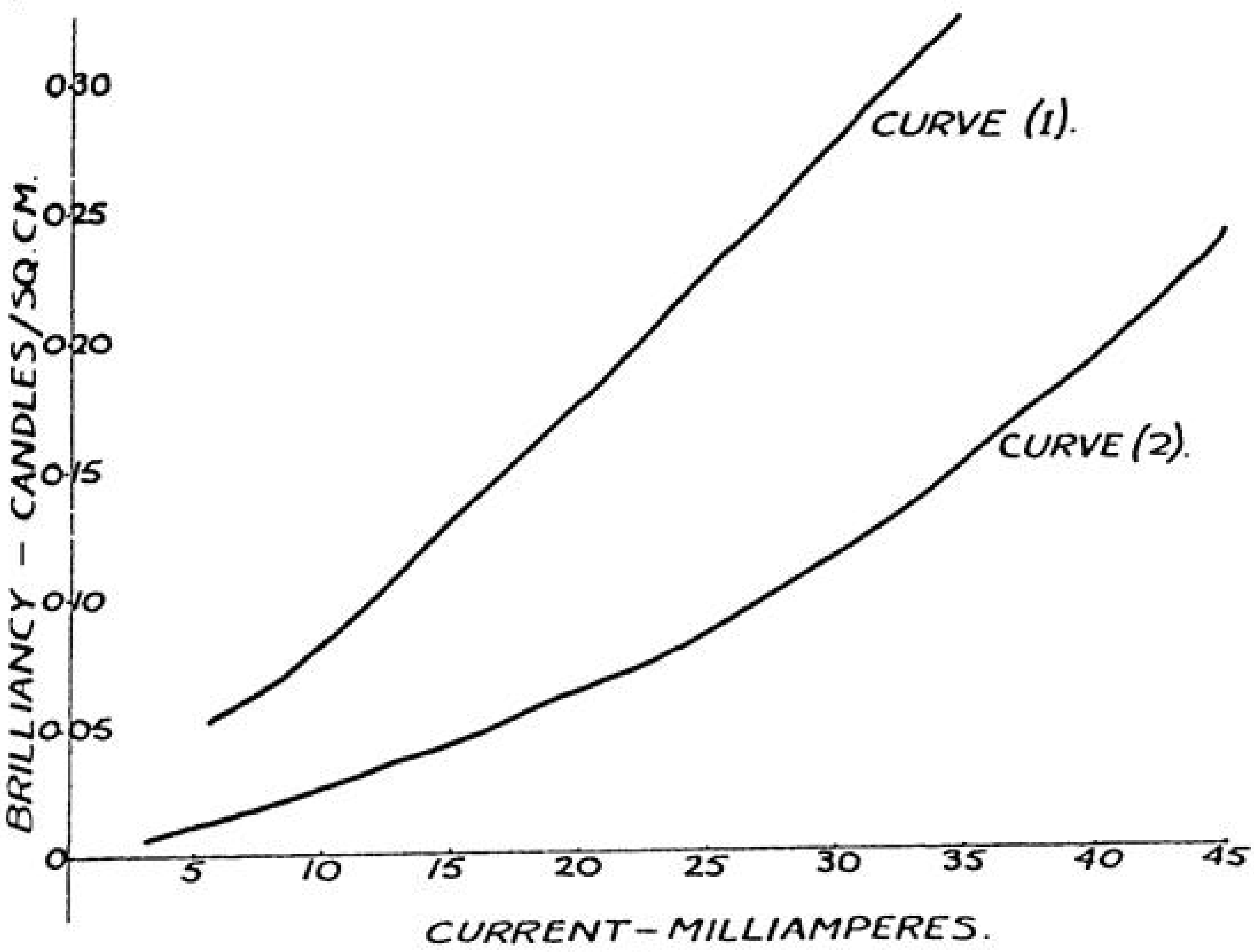

Fig. 5.

filters are affixed over the apertures of the disc, as at the transmitter, but, in addition, the receiving apertures are covered with a light-diffusive medium (frosted gelatine is found very suitable) in order to increase the angle in front of the disc over which the image may be seen.

The current-brilliancy characteristics of the discharge-tubes are given in Fig. 5, in which curve (1) refers to the neon, and curve (2) to the mercury tube. The response of these tubes to rapid variations of current is more than adequate for low-definition work,[21] and they can, with suitable precautions not to extinguish them completely and correct choice of gas-pressure, be made quite stable in operation ; the pressure is between 8 mm. and 12 mm. for normal working temperatures.

(4) RESULTS AND TREND OF FURTHER RESEARCH

A description of the very simplest possible colour-system has been given in the foregoing in order to bring out the manner in which the various parts of such a system are related to each other. It is of interest, however, to remark upon the results achieved with it. Dr. Russell, Principal of Faraday House, writing in *Nature* (18th August, 1928), said—

> The colour-images we saw which were obtained in this way were quite vivid; delphiniums and carnations appeared in their natural colours, and a basket of strawberries shows the red fruit very clearly.

The system was demonstrated later in the year in the Engineering Section of the

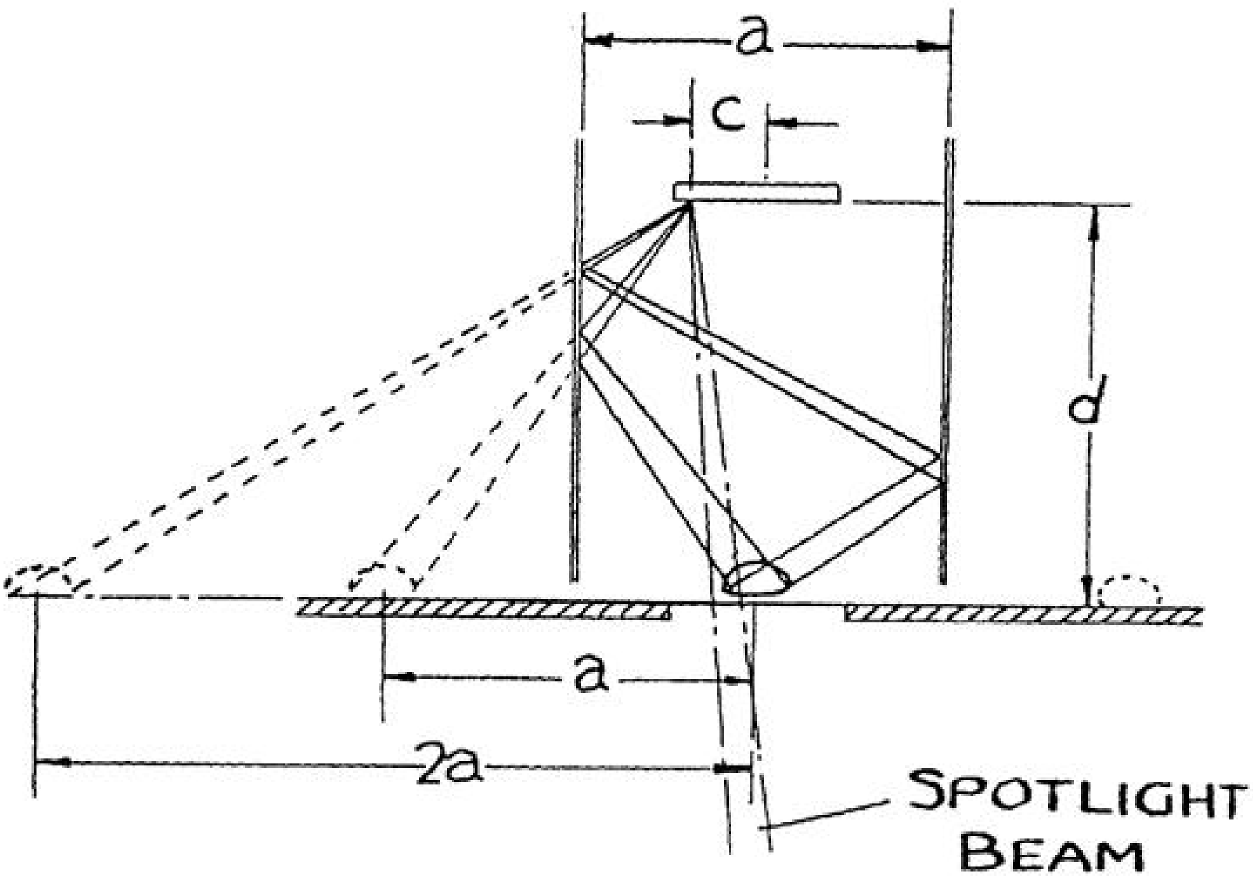

FIG. 6.

meeting of the British Association at Glasgow, the scene of Mr. Baird's work. The images transmitted, consisting as they did of only fifteen elemental strips, showed a surprising amount of detail: in the human face, the whites of the eyes, the colour of a protruded tongue, and the teeth were clearly reproduced. Mixtures of strawberries, raspberries and leaves were recognisable: not only the colours but the tones and shades of irises, poppies and marguerites could be seen. The chief difficulty occurs, of course, with whites, in which the relative strengths of red, green and blue have to be carefully balanced: fortunately, the visual accommodation is large,[22] however, and it is remarkable to what extent light may differ from white and yet appear but slightly tinted.

An important extension of the apparatus must now, in conclusion, be noticed which has a bearing upon the improvement of the signal-ratio; the effect of adding photocells at the transmitter may be obtained, as a little consideration will show, by placing surfaces close to the object so that an additional quantity of diffused light from the object reaches the cell indirectly, after one or more reflections.* This gives us an opportunity of increasing the relative response to any colour by using *coloured reflectors*: for example, to increase the effective red-response of the photocells, pieces of silvered red glass may be arranged at the sides of the object, as shown in Fig. 6. Imagining a single photocell to be situated directly before the object, as shown, the effect of the mirrors is equivalent to placing an infinite series of additional cells spaced out on either side of the true one, at distances equal to the distance apart of the mirrors.

Now, the distance of the *n*th "mirage" cell from the spot of light on the object is given approximately by :—

$$d_n = \sqrt{d^2 + [(n-l)\ a + c]^2}$$

the light reaching the true cell in this way, after *n* reflections, is proportional to l_n where :—

$$l_n = \frac{k^n d}{\sqrt{\{d^2 + (na + c)^2\}^3}} + \frac{k^n d}{\sqrt{\{d^2 + (na - c)^2\}^3}}$$

and the light reaching the cell direct is, of course, $l/(d^2 + c^2)$, where :—

a is the distance between the mirrors,

c is the distance of the light spot from the median plane,

d is the distance of the object-surface from the cell,

and *k* is the coefficient of reflection of the mirror.

A rough calculation, putting $k = 0$ and assuming *c* to be perpetually zero (as it will be at least once during every traverse) shows that the total light reaching the cell by way of three reflections will be less than $\frac{1}{10}$ of that reaching it direct, so by putting $k = 0.7$ and giving *n* the values 1, 2 and 3 successively, we see that, with the mirrors as far apart as the object is from the cell, the effect of the mirrors is to increase the effective light on the cell from *l* to *L*, where :—

$$L = l(1 + 0{\cdot}49 + 0{\cdot}0874 + 0{\cdot}0218 + \text{etc.})$$
$$= 1{\cdot}6 \times l \text{ approximately.}$$

The effect of coloured spotlights in stage-lighting can also be obtained in colour-television by providing certain cells, or batteries of cells, preferably in conjunction with lenses, with colour-filters of the colour of the spot-effect required, and directing these selectively-responsive photocells towards that portion of the scene upon which the coloured halo is desired. Of course nothing is seen at the transmitting end, but in the received picture a "stage spot" effect will be produced, the brightness of which can be controlled by altering the degree of amplification associated with the particular bank of photocells concerned.†

* See specification of British Patent No. 320627 (J. L. Baird).

† See specification of British Patent No. 333942 (J. L. Baird).

Coloured cinematographic films can also be transmitted by television, by somewhat different process, and in the future this aspect of television is likely to have important applications in entertainment. Many of the processes involved in colour-transmission are considerably simplified by the "intermediate-film" method, which comprises taking a cinematograph film at the transmitting end, continuously developing it, and scanning it to derive a television signal. This method, either by the single-film or by the triple-film colour process in cinematography, can easily be seen to be applicable to colour-television, with advantages, for example, in the fact that the photocells themselves, instead of having to be sensitive over a wide range of colours, need only be responsive to the scanning light once the film has been made.

PART B

(1) THEORIES OF COLOUR-VISION:

(*a*) THE GOETHE-NEWTON CONTROVERSY

In bringing before the Society of Arts, embracing as it does the artist in pigments and the artist in philosophy, a brief attempt to answer the still controversial question of how we perceive sensations of hue and tone in colour, it is difficult to formulate a method of attack which will not offend either the æsthetic or scientific susceptibilities. The artist is concerned solely with the "beautiful show" which makes it possible to contemplate the ideal; even nature is, in his eyes, but the sensible expression of the spiritual. The natural philosopher, on the other hand, tries to discover the levers, cords and pulleys which work behind the scenes, and, of course, when these are dragged to light, it spoils the beautiful show. It will be best, therefore, to notice very shortly the opposing views which early separated and have appeared in varying guises ever since. The classical view is that of Newton, and it is characteristic of Goethe that he should have been the first[11] to break a lance with scientists over the matter.

Newton's theory[12] is based on the hypothesis that there exists light of different kinds, distinguished from one another by the sensation of colour which they produce in the eye. Thus there is red, orange, yellow, green, blue and violet light, and light of all intermediate colours. Different kinds of light, or differently coloured lights, produce, when mixed, derived colours which to a certain extent resemble the original colours and to a certain extent form new tints. White is a mixture of all the above-named colours in certain definite proportions. But the primitive colours can always be reproduced by analysis from derived colours or from white, while themselves not susceptible of analysis or change. The cause of the colours of opaque and transparent bodies is that when white light falls upon them they destroy some of its constituents and send to the eye other constituents, but no longer mixed in the right proportions to produce white light. Thus a piece of red glass looks red because it transmits mainly red rays. Consequently all colour is derived solely from a change in the proportions in which