Some Optical Features in Two-Way Television *

By HERBERT E. IVES

A comprehensive description of the two-way television system now being demonstrated between the American Telephone and Telegraph Company building, and the Bell Telephone Laboratories, in New York City, has been published elsewhere.[1] Part of that account gives the essential features of the optical arrangements whereby the users of the apparatus are appropriately lighted, and are assured against visual discomfort from the scanning operation. Since the apparatus was first installed, however, some important changes have been made in the distinctively optical features, whereby the performance of the system has been notably improved, and its operation considerably simplified. These changes deserve description, and the present account is mainly concerned with them, although for the sake of completeness some details previously described are included.

IT IS an inherent feature of the two-way television system that either user is continuously scanned as he views the image from the distant station. The beam scanning method,[2] by which a beam of light sweeps over the subject's face, enables the scanning operation to be performed with a minimum amount of light. Even so, because of the relatively low intensity of the television image, it is necessary to reduce the intensity of the scanning beam in every way possible. In the two-way apparatus as first operated, advantage was taken of the fact that the photoelectric cells employed, which were of potassium, were principally sensitive to blue light. The scanning beam derived from a high power arc lamp was accordingly passed through a deep blue filter, which reduced the photoelectric efficiency of the beam very little, but because of the relatively low visual value of blue light, effectively reduced the brightness of the beam many times. The user of the apparatus saw, above the incoming image, merely a mild blue spot of light, which did not interfere with his vision.

A disadvantage of the use of blue light, which was anticipated, and found in practice to be quite real, was that dark, tanned, or ruddy complexions were rendered as altogether too dark, in comparison with whites such as the ordinary linen collar. The effect is precisely that encountered in the earlier photographic processes before color sensitive plates and color filters were available. While this defect was minimized by the use of a dark background, and to some extent by chopping off the highlights by electrical means, it was recognized as undesirable.

* *Jour. Optical Soc.*, Feb. 1931.

[1] *Bell Sys. Tech. Jour.*, July 1930.

[2] *Jour. Optical Soc.*, March 1928.

One recent improvement in the apparatus is a change in the nature of the scanning light, whereby, without sacrificing the general principle of using visually inefficient but photoelectrically efficient radiation, the proper balance of tone values in the face is restored. This has been accomplished by adding to the battery of blue sensitive potassium cells, a group of red sensitive cæsium oxide cells, and scanning by *purple* instead of blue light, that is, both ends of the visible spectrum are used in place of one end.

In making this change, a number of others were involved, most of which resulted in simplification or improvement. One important alteration was the substitution for the arc lamps previously employed, of incandescent lamps of a type available from motion picture projection practice, as shown in Fig. 1. The lamp employed has for its radiator, four vertical helical coils of tungsten wire, and is furnished with a reflector which images the coils back on the intervening spaces. An efficient condenser system throws a brilliant rectangular image on the back of the scanning disc, which is substantially uniform over the whole field. With this unit, the scanning beam as it leaves the projection lens is somewhat larger in diameter than the beam as produced from the arc. Consequently, for positions away from the focused image of the disc holes, the scanning beam is larger than before, with some resultant loss in the range of sharpest definition. Since, however, the user of the two-way apparatus is seated in a fixed chair, he has little opportunity to move far out of the plane in which the disc holes are focused, so that this objection is not serious. The advantages of this substitution were two-fold. First was a great gain in simplicity of operation and maintenance. Second, the incandescent lamp, being a lower temperature radiator, radiates relatively many times as much red light as does the arc, for the same amount of blue. Consequently, once an incandescent lamp unit was found which gave the amount of blue light required for the potassium cells, the great excess of red light made possible the use of relatively few cæsium oxide cells. Since these are intrinsically somewhat more sensitive than the potassium cells, the net result was that a red signal comparable with the blue signal could be added by the installation of only two cæsium cells, each of less than half the electrode area of the potassium cells.

It was found most convenient to mount the two cæsium oxide cells directly in front of the observer, to either side of the microphone, and above the opening in the booth through which the scanning beam enters, and through which the incoming image is seen. This arrangement is shown in Fig. 2. The only objection to placing the cells in this position is that they encroach somewhat into the region where reflections of the cells (which are virtual light sources) are likely to be seen reflected in eyeglasses. Since, however, the head is normally directed somewhat downward, cells placed in these upper corner spaces are not serious offenders in this respect.

Two other features of the two-way system which needed revision when the cæsium cells were adopted, were the variable angle prisms used to direct the scanning beam upward or downward, depending on

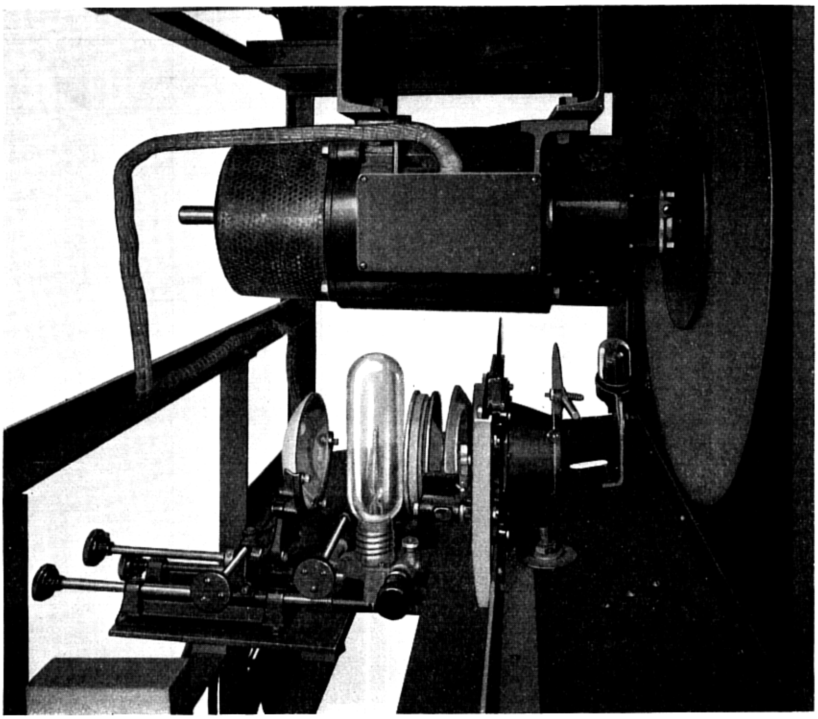

Fig. 1—Incandescent lamp used for scanning light.

the user's height, and the general illumination of the television-telephone booth. As to the variable angle prisms, the only change called for was the substitution of achromatic prisms, corrected for deep red and blue light, in order to prevent the scanning beam from breaking effectively into two beams for large angles of deviation. The problem of general illumination of the booth is principally the choice of a color of light which shall affect neither the potassium nor the cæsium cells. For this purpose, a monochromatic yellow-green was chosen, secured by covering all the lights with a combination of orange and signal green glasses. The potassium cells are insensitive to this color of light, and the cæsium cells were rendered so by placing over them, windows covered with a deep purple gelatin. This choice of illumination color made possible a satisfactory general level of illumination of the booth and the surroundings of the image without introducing spurious signals.

The transmissions of the purple filters, the response curves of the potassium and cæsium oxide cells, the radiation curve of the incandescent lamps used for the scanning beam, and the transmission curves of the glasses used over the lamps for general illumination, are shown

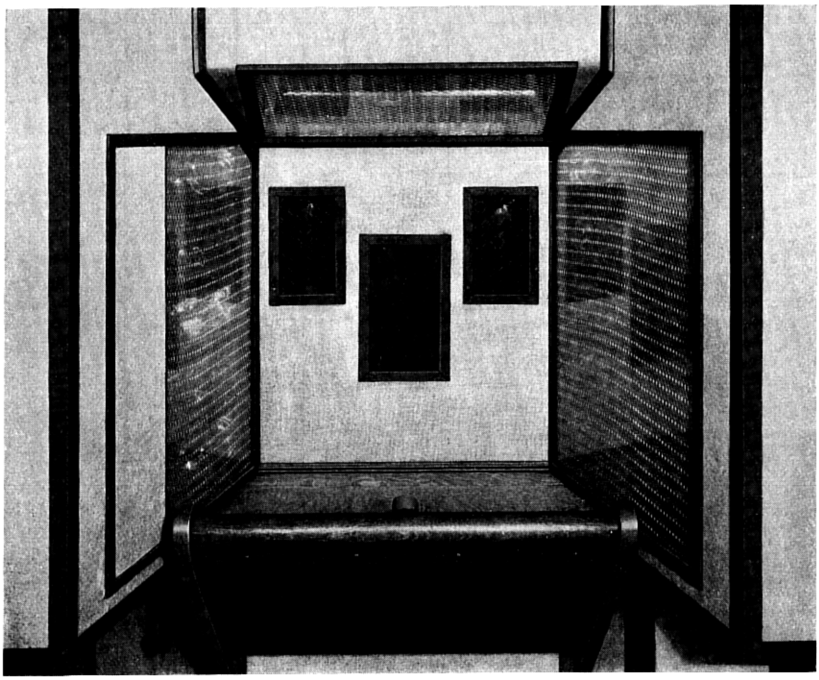

Fig. 2—Interior of two-way television booth showing location of two cæsium cells above and to either side of scanning and viewing aperture.

in Fig. 3. Comparing these with the response curve of the eye, also shown in the same figure, it will be evident how the general problem of securing photoelectric signals of maximum efficiency without interfering with the general quality of the image, or desirable conditions of illumination, has been secured.

Before going on to describe some of the optical features at the receiving end, we may pause to discuss the improvements in the television signal which have been introduced by the changes just described. There is, of course, a substantial gain in the steadiness of the image due

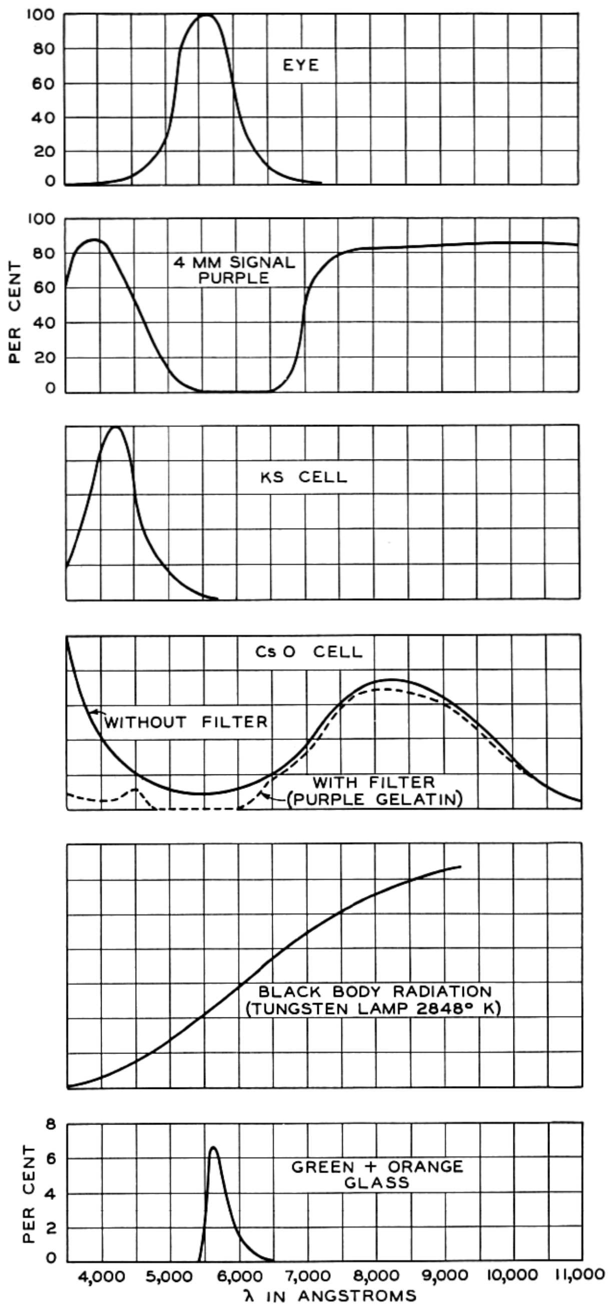

Fig. 3—Spectral characteristics of the scanning, viewing and illumination elements in two-way television system.

to the elimination of the arc lamps, much of whose effective radiation was from the arc stream which always wanders somewhat. The chief gain, however, is in the tone quality of the image of the face. The difference is very clearly shown if shutters are arranged so that either the potassium or the cæsium cells may be used alone, alternately, and can then be quickly exposed together. With the potassium cells alone, as already noted, flesh tints are in general too dark, and tanned or ruddy complexions show unnatural contrast with the whites. Highlights due to reflection on the skin are often observed to be out of scale, with a resultant effect of mottling of the skin. With the cæsium cells alone, on the other hand, the flesh tints are in general too light, and faces are apt to appear very flat. These differences were anticipated, but others not so obviously to be expected, have been observed. For instance, with the cæsium cells, the pupil and iris of the eye are brought out with rather startling blackness, while with the potassium cells, the detail around the eyes is apt to be lost. The most satisfactory results are obtained with both sets of cells acting, for, as was hoped, the combination of the two ends of the spectrum, gives, in the case of the face, an effect very like that which light from the middle of the visible spectrum would give, that is, an "orthochromatic" image, as it would be described in photography, while the definition of important points, such as the eyes, is distinctly improved.

Passing now to the receiving end of the two-way television apparatus we recall that in the apparatus as originally set up and described, a simple disc with a spiral of holes was used, immediately behind which was a neon lamp with a large flat water-cooled electrode. On continued operation, it was found that the heavy current demanded in these lamps, in order to secure an image of sufficient brightness, caused rapid sputtering on the closely adjacent glass wall, necessitating frequent renewals of lamps. A very radical change in the disc and lamp design has been made by which this undesirable situation has been remedied.

The change in the disc consists in substituting for the simple Nipkow disc, with its spiral of holes, an alternative form, suggested also by Nipkow, in which each disc hole has associated with it a condensing lens, positioned so as to focus, in combination with a fixed collimating lens, and image of the source on the disc hole. The optical arrangement is shown in Fig. 4, and a photograph of the disc with lenses and lamp in place in Fig. 5. Referring to Fig. 4, D represents in section the simple disc with a spiral of holes, h; l represents a small short focus lens, fixed in position with respect to h at a distance equal to its focal length; L represents a fixed lens of diameter large enough to cover the

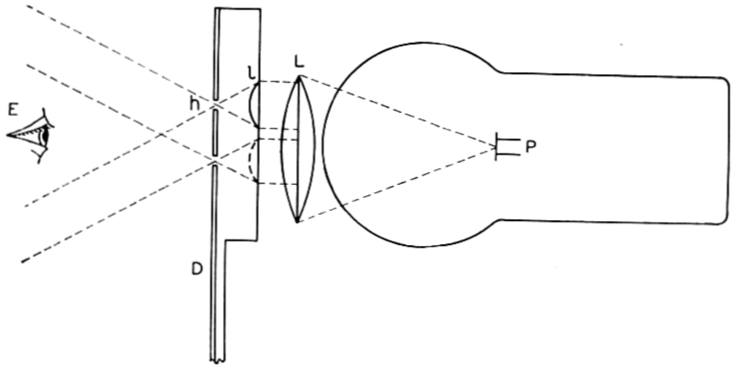

Fig. 4—Section of disc with lens system for utilizing small area light source.

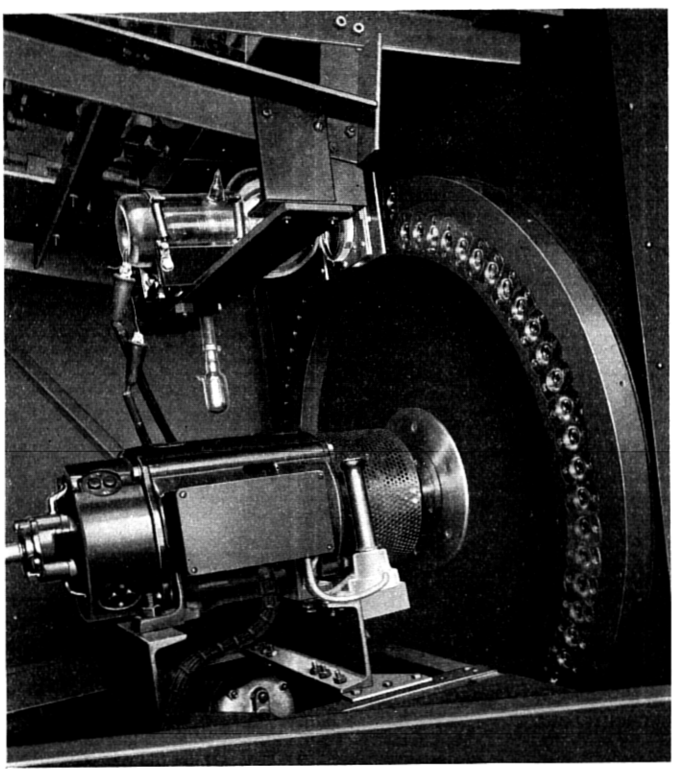

Fig. 5—Disc with condensing lenses as used at the receiving ends of two-way television system.

entire frame of the picture and the lenses l; P represents the glow lamp electrode. A great advantage of this optical arrangement is that the cathode of the glow lamp can be made quite small, and can be removed, as shown, to a considerable distance from the glass wall of the containing tube. In consequence of these changes in lamp design, a very high current density can be obtained for a relatively low expenditure of energy, with at the same time a long lamp life.

The condenser lens disc is observed exactly as the simple disc, by the eye placed at E. According to Nipkow, when lenses are used on the disc, the holes should be covered with diffusing material. This is not necessary in the present case, because in the two-way booth, the observer has very little latitude of motion, and it is only necessary that his eyes lie in the overlapping cones of rays from the extreme holes in the field. By making the lenses l of large diameter compared with their focal length, the solid angle through which an image is visible is entirely adequate.

The general characteristics of the lamps used are shown in Figs. 4 and 5. The cathode is a heavy slug of copper, into which a hollow cylindrical aluminium electrode is screwed, shielded from the copper by mica and glass. Because of the large mass of the copper, the water-cooling is no longer necessary. With lamps of this type, the amplifier circuit used before makes it possible to obtain images of much greater brilliancy, whereby the contrast between the image and the scanning light is still further increased beyond what was before found satisfactory. This margin of brightness is so large that it has been found possible to use lamps filled with helium in place of neon, giving a much whiter image, more pleasing to some people.