ABSTRACT

High-Diffusion Screens for Process Projection

By Hugh McG. Ross

I. Requirements of Translucent Screens

One essential difference between front and back projection lies in the manner in which light leaves the screen and enters the lens of the camera or the eye, and to consider this we must imagine the film or slide removed from the projector and the blank screen illuminated. The distribution or unevenness of the brightness of the screen which is then seen will still be present when the picture is superimposed upon it, In back projection very little light is reflected; most of it passes through the screen and is scattered to some extent. The effect is shown diagrammatically in Fig. 1. The angle between the incident ray and the screen makes little difference in the shape of the curves. However, when the screen is photographed or observed from the camera position, the intensity of the light coming from the center of the screen is greater than the intensities from the edge and corners. This explains the existence of the well-known "hot-spot" characteristic of back projection.

The magnitude of the nonuniformity of the screen brightness depends upon the angle through which the light must be diffused in passing from the projected light beam to fall on the camera lens. This angle is the sum of the angles from the camera and projector lenses. The values of such angles at the corners of the screen for various projector and camera lens focal lengths is shown in Table I. For the great majority of process shots the total angles

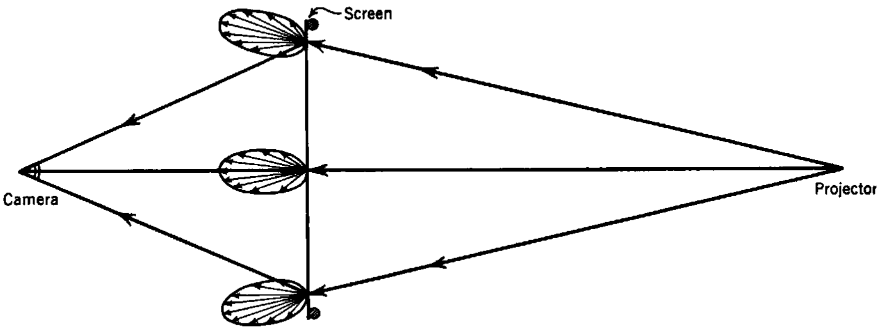

Fig. 1. The way in which light is scattered on passing through a diffusing screen.

The length of each arrow represents the intensity of the light in the direction of the arrow, and the polar curve joins the tips of the arrows.

Abstract by F. B. Berger of a paper by Hugh McG. Ross, published in *J. Brit. Kinemat. Soc.*, vol. 16, no. 6, pp. 189–199, June 1950.

Table I. Camera and Projector Lens Angles

35-Mm Camera Lenses								
Focal length, mm...	25	28	35	40	50	75	100	
Corner angle, deg..	28.6	25.9	21.2	18.8	15.2	10.3	7.8	
35-Mm Process Projector								
Focal length, in.....	2	3	4	5	6	7	8	9.25
Corner angle, deg...	16.4	11.1	8.4	6.7	5.6	4.8	4.2	3.6
Still Projector, 3 × 2.2 in.								
Focal length, in.....	6.4	8	10	12.5	14	16	18	22
Corner angle, deg...	16.2	13.1	10.5	8.5	7.6	6.6	5.9	4.8

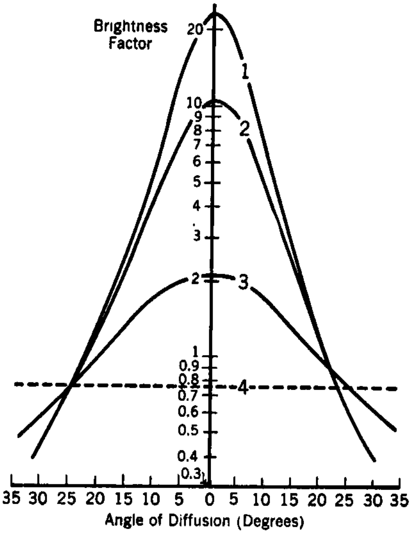

Fig. 2. A preferred way of drawing the polar diagram.

Curve 1: measured at corner of typical graded screen in normal use.
Curve 2: measured at center of the same screen.
Curve 3: new high-diffusion screen.
Curve 4: nominal performance of good front-projection screen for comparison.

range from 15° to 30°. An examination of the data shows that the camera lens, being generally of shorter focal length, contributes far more than does the projector lens to the total angle. A convenient rule of thumb is that the projector throw should be about twice the camera throw, and it is unnecessary to make the projector throw greater than this.

For quantitative considerations the data are more conveniently presently in the Cartesian form, as in Fig. 2, in which brightness is plotted logarithmically against angle for several screens. The measurements were made by projecting a steady light on the screen and observing the brightness of several test areas of the screen from different angles, using either a Morgan Reflectometer or the S.E.I. Visual Photometer. The units used represent the brightness which would be obtained if the incident light were reflected back by a Lambert surface, a perfectly white matte reflector, and may be termed the "brightness factor."

If a uniform screen is used, made with the same thickness of diffusing material all over its area, the brightness across the screen, as observed from the camera position, is rather similar to this polar curve. If, on the other hand, a nonuniform or graded screen is used, made with additional diffusing material near its center, the complete brightness distribution curve cannot be assessed so easily. For example, the two upper curves of Fig. 2 are for the best type of graded screen hitherto available. These curves show that if the projector side of the screen is uniformly illuminated, the center is fifteen times brighter than the corners at 25°. The hot-spot produced in such a case may be partly overcome by placing metal discs in the center of the light beam. These discs reduce the intensity of the light falling on the center of the screen, but with skilled use they need not reduce the intensity of light falling on the edges and corners. They have the serious practical disadvantages that it takes considerable time to position them, and the movement of the camera is restricted.

Curve 3 of Fig. 2 illustrates the new high-diffusion screen. The first important point is that the center is only two or three times as bright as the corners. This overcomes the hot-spot effect, and considerable experience with these screens has shown that the great majority of back-projection shots, including Technicolor, may be thrown up on the screen without any hot-spot being noticeable. This curve is found to be better than an even more uniform one.

The second important point is that the brightness of the corners of the picture is as great as with the older screens, so that no increase of camera exposure is required.

The new screen possesses several distinct advantages from the practical point of view. These are:

1. The camera may be moved parallel to the screen surface without having the average screen brightness or light distribution change to any objectionable degree.

2. The camera may also be freely moved in a direction normal to the screen surface.

3. The freedom in panning and tilting the camera without objectionable changes in average brightness or uniformity is considerably greater with the new screen.

4. The accuracy with which the optical axis of the projector is aligned with the camera axis and with the screen is much less critical than with older screens.

All the effects described are independent of the scale of the setup. Larger pictures require simply greater light output from the projector to maintain the same brightness as for the smaller picture. Even the definition is not affected.

The best method of making light measurements on a diffusing screen is to use a narrow-angle photometer while standing at the camera position, the S.E.I. Visual Photometer having proved particularly suitable.

II. Experimental Study of Screen Properties

A systematic study has been made of diffusing materials for screens with a view toward finding out which qualities are important for the quality of the screen and also which other qualities have no useful effect. Both the diffusing material and supporting material must be colorless and should be unaffected by age, weather conditions or washing. The base material is preferably a plastic. The most suitable are ethyl cellulose or ethyl acetate. Finely powdered optical glass was chosen as a satisfactory diffusing material.

Another important factor is that the straight-through brightness factor be not too great (to reduce hot-spot) and that the brightness factor at angles of about 25° be as much as possible to ensure high corner brightness.

Over a wide range of samples, an increase of diffusion reduces the straight-through brightness factor but makes little difference at 25° or 30°. This effect gives control over hot-spot.

A number of typical brightness vs.

angle curves are presented in the paper. A study of the results shows that the following factors do not affect the optical properties of the screen:

1. It does not matter whether the diffusing particles are on or near the surface or are embedded throughout the base.
2. It makes no difference whether the diffusing material is incorporated in the liquid base plastic and cast, or whether the screen is built up by spraying a mixture of diffusing material and plastic lacquer.
3. The same diffusion is obtained by one high-diffusion screen or two low-diffusion screens placed close together. The latter, of course, may affect resolution in certain cases.
4. Over a considerable range, the size of the diffusing particles makes no difference. It is probable that the optical characteristics are chiefly controlled by the number of particles rather than the total weight. The largest particles should be considerably smaller than the screen thickness and the smallest should be several times the wavelength of light.
5. It is immaterial whether the diffusing particles are of uniform size or mixed.

The most important fact revealed by the investigation is that the shape of the polar diagram may be altered by changing the refractive index of the material used for the diffusing particles, so that by the correct choice the corner brightness is made as high as possible. Almost certainly the important criterion is the difference between the refractive indexes of the plastic base and the diffusing particles, but the indexes for all suitable plastics are similar so that the index for the particles is the most relevant. Experimentally, the preferred index is about 1.6 to 1.7, although no theoretical explanation has yet been established as to why this is the case.

III. Method of Manufacture of Screens

The use of powdered glass for high-diffusion screens is covered by British Patent 27,812 (1949). Essentially a method of making the screens consists of spraying a cellulose lacquer onto a false ceiling, powdered glass being mixed with the lacquer for some of the layers.

The ceiling used is constructed of ordinary trowelled plaster on the usual laths, supported from a suitable framework. The spraying is done from below. The plaster is first prepared by spraying it with a suitable gelatin solution. It is followed by applying a layer of ethyl cellulose lacquer with a spray gun. Fabric tapes are then applied to strengthen the edges of the screen. The powdered glass is next sprayed on, this being the most difficult part of the process since uniformity of coverage must be achieved. The powdered glass is mixed into the lacquer for spraying, a true wet spray being obtained. After drying two or three days, the screen is stripped off the gelatin-treated plaster. Eyelets are put into the edge-tapes, and after the screen has been laced into a frame it is ready for use.