Optical Display for Data-Handling System Output

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INTRODUCTION

DUE TO long experience in the field of business machines, Burroughs has always been alert to the fact that human operators are important links in most computing and data-handling systems. Because of its versatility, this link fills in where unattended techniques are still insufficient, where decisions must be made in problems of extremely variable or unpredictable nature, and where monitoring and manual intervention may be needed due to functional failure.

One type of display device has been developed at the Burroughs Research Center for conveying to operating personnel the output information of data-handling systems. These devices utilize an optical medium known as a lenticular screen. Such a medium consists of a large number of very small lens surfaces, either cylindrical or spherical, placed substantially in one plane of the lenticular screen and having a common focal plane in which are recorded in a space-sharing fashion the image elements of prerecorded messages.

Electronic engineers may be more familiar with the lenticular structure as used in the Lawrence television tube than with optical lenticular screens. The functional similarities are there, but the methods of design treatment, the various degrees of freedom, and the techniques of creating physical embodiments are sufficiently different to preclude considering the electronic and optical lenticulars as equivalent.

There have been numerous commercial applications of the lenticular medium. Its first major appearance was in decorative, dispersing, window glass not uncommon about 50 years ago. Here the cylindrical ribs, 0.1 to 0.5 inch wide, served the purpose of presenting a repeated series of prism angles effecting a transverse dispersion. No precision was required. The same principle is used in some rear-projection screen designs and in single azimuth dispersion of light sources such as sealed-beam lamps.

These applications utilize lenticular screens without need for any precise focal plane and no image information is carried by the screen itself. The minimal precision allows some of these to be made of molded glass. In other uses of the medium, the focal plane of the lenticules has an important function and carries prerecorded image information. Here the additional precision usually prescribes that the lenticular elements be molded or cast in plastic. We will mention a few; their geometry will become clear when we describe the principles of lenticular output-data displays.

In one type of three-dimensional photography, the lenticular screen is used for displaying consecutively different aspects of an object as might be seen by walking around the object, each aspect being visible only to an observer's eye viewing the display at the angle from which the aspect was photographed. Within certain audience limitations, the two eyes of the observer can see two different aspects, thus giving true binocular vision of the object. Likewise, a simpler use is that where unrelated images are made to appear consecutively as an observer's angle changes. These unrelated images may be messages which appear to flash on and off, eyes that wink, and other more or less sophisticated material.

BURROUGHS LENTICULAR DISPLAYS

An optical design is usually interesting in that it can be operated in either direction, in other words, the ray trace is usually reversible. This is the case in the lenticular screen. We note immediately that if an illuminator is substituted for the observer in the last examples given, only that image which the observer was able to see will be illuminated (see Fig. 1). Now if a device is constructed containing at its rear end a number of lamps or a plurality of filaments, there will be associated with each illuminator discrete areas, one for each lenticule, in the focal plane of the lenticules. In the case of cylindrical lenticules, these will be narrow lines; in the case of spherical lenticules, these will be small areas the shape of which will depend upon the configuration of the filaments. Now if the focal plane of these lenticules carries a photographic emulsion and if a stencil or negative is interposed between a light source and a lenticular screen and if this light source is made to occupy consecutively the positions of the filaments in the final device, it will be sufficient to make as many exposures as there are messages, substituting a new negative each time the light source is moved to a new position. An appropriate diffusing screen placed over the developed lenticular will allow the illuminated image to be visible to a sufficient audience.

TECHNIQUE AND DESIGN CONSIDERATIONS

A number of difficulties is encountered in the use of this technique. First is the art of engraving master-die surfaces in order to generate with adequate precision and optical quality the minute surface elements involved. Another is that of designing a system in which there is, in general, only one surface to work with. Ordinarily an optical device, such as a photographic lens, will have a number of air-to-medium surfaces, thus enabling the optical engineer to introduce the necessary corrections to

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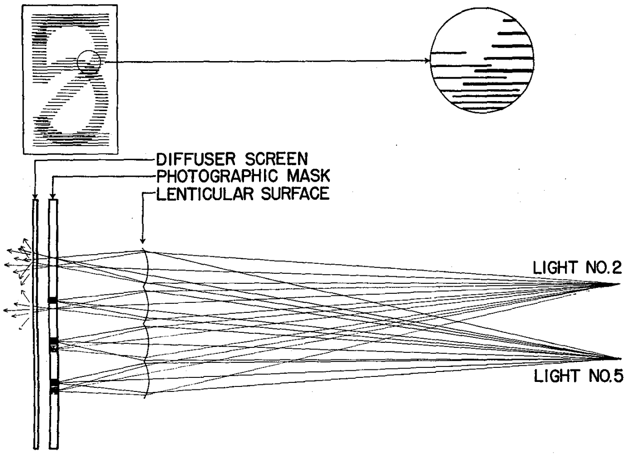

Fig. 1—Geometrical schematic of one-azimuth lenticular digit display. Two of the ten light sources are shown with their associated ray trace and image records. Lenticular screen carries cylindrical surfaces with horizontal axes.

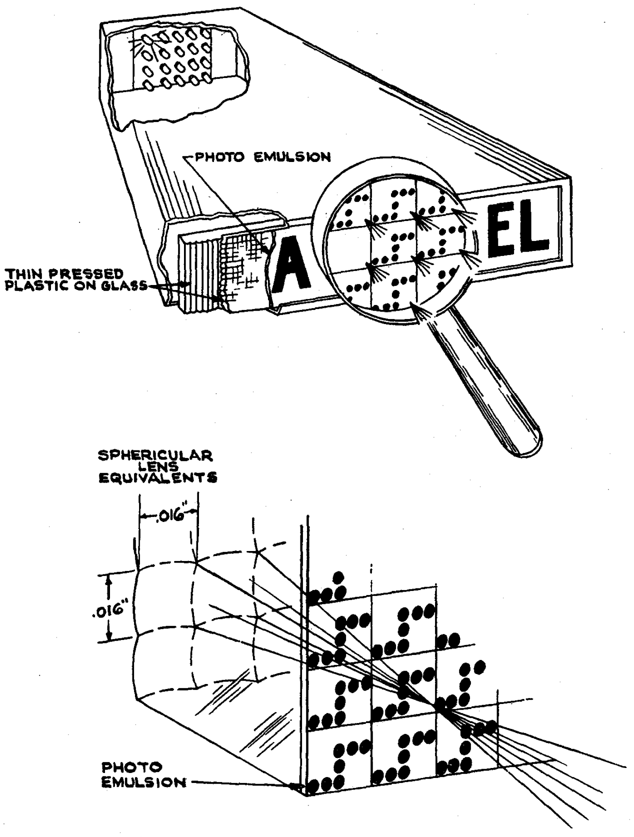

Fig. 2—Two-azimuth lenticular display. Ray trace through screen shown for "equivalent sphericles."

assure that a substantial number of discrete image points can be resolved through the desired pupil. We have found that cylindrically-ribbed (*i.e.,* single azimuth) lenticular media can be made to resolve up to 10 images with adequate lack of crosstalk for a display purpose.

A practical technique for constructing two azimuth lenticular screens consists of placing two cylindrically-ribbed screens face to face with the axes of the cylinder of one screen at right angles to those of the other. The adjoining boundaries of the cylindrical elements now define square cellular pupils within each of which the refractive performance is similar to that of a spherical element (see Fig. 2).

Two azimuth systems of crossed lenticular structure can resolve in excess of 20 separate channels.

We have found that the quality of a screen image as seen by an observer does not yield readily to analysis into quantitative information of brightness, contrast and crosstalk, and that partly empirical designing and direct observation of models are still the most reliable ways of obtaining a conclusive analysis of a new application.

The light-handling capacity of these displays is of some interest because its analysis will largely determine the class of light source which is necessary today. If we consider the image-record plane, it is immediately clear that the luminance of any image area can never exceed that of the source divided by the number of messages. Considering further that the relative aperture of each lenticule is limited by optical-design considerations, we find that a further luminance reduction will occur as the outcoming flux is dispersed in order to satisfy a suitable audience, (except in certain special cases where a restricted audience can be tolerated). Further, certain clearance margins in the optical geometry must be allowed. These must take into consideration the mechanical tolerances of the light sources themselves, the mechanical tolerances of the assembly, the geometrical optical aberrations of the rudimentary lenticules, the phenomena of physical optics (since these lenticules are usually very small), and the remaining imperfections in the manufacture of the lenticules. When all these factors are taken into consideration, as well as the absorption factors which are inevitable in a system involving several surfaces, we find that the only practical illuminators for applications where the ambient light is of an office level (30 to 60-foot candles) are tungsten filaments and that further, for practical reasons, these tungsten filaments should be operated at low enough temperature so as to obtain consistently acceptable life. Typical embodiments specify filament currents from 80 to 200 ma and wattage from 0.5 to 1.5.

Logic and Economy

The information-handling capacity of such a device is of some interest. If there are N channels or resolved images in each of L "sphericules" in the crossed lenticular system, then the total information recorded in this system should be NL bits. Clearly, the same information could be handled in a system having N objectives provided that each of such objectives was able to resolve L bits of image information. We are familiar with the 35-bit (7×5) minimum matrix for the presentation of an individual alphanumeric character. One also finds immediately that reading reliability and operator acceptance increase rapidly if the number of bits per alphanumeric image is increased,