Another solar line which we have now detected at high altitudes is the 4-6 transition, lying in the 2.6μ water-band. The presence of this line will produce slight corrections to some of the water-vapour concentrations calculated by Houghton and Seeley².

Full results of our measurements are being submitted to the Royal Society for publication in the *Philosophical Transactions*.

N. D. P. HUGHES
T. S. MOSS

Royal Aircraft Establishment,
Farnborough, Hants.

¹ Houghton, J. T., Moss, T. S., Seeley, J. S., and Hawkins, T. D. F., *Nature*, **180**, 1187 (1957).

² Houghton, J. T., and Seeley, J. S., *Quart. J. Roy. Met. Soc.*, **86**, 358 (1960).

PHYSICS

Line-Spread Functions of Photographic Emulsions

THE detail-recording ability of a photographic emulsion may be tested by exposing it through a very narrow slit, and, after processing, measuring the variation of density with distance, x , from the centre line of the image. When the scale of density is transformed into a scale of effective intensity of illumination, the result is the line-spread function, $B(x)$.

Traditionally, the 'double-exponential' function¹⁻³ is taken as a convenient model for the analytical representation of measured results. For the present purpose, this function may be expressed as:

$$B(x) = \pi F \exp(-2\pi F|x|)$$

Its Fourier transform, the sine-wave response function, is:

$$Y(f) = 1/\{1 + (f/F)^2\}$$

where f is the spatial frequency and F is the value of f such that $Y(F) = 0.5$. In generalized form, these functions are shown as the dashed curves in Figs. 1 and 2. Some workers, however, have indicated dissatisfaction with this model, referring either to its physically unlikely sharp peak and central discontinuity or to the related slow fall of sine-wave response at the higher frequencies. Various modifications have been proposed, but most involve at least one additional parameter.

Fig. 1. Line-spread functions

Fig. 2. Sine-wave response functions

In the course of work on television image structure, it has been noticed that the 'fourth-power cosine' function, as it may be termed, offers advantages as a model line-spread function. Expressed in terms of a length parameter, D , the function is:

$$B(x) = 2 \cos^4\{\tan^{-1}(x/D)\}/\pi D \\ = 2/\pi D \{1 + (x/D)^2\}^2$$

or, in terms of the parameter F already defined:

$$B(x) = 2AF/\pi \{1 + (AFx)^2\}^2$$

where $A = 3.7437$. The corresponding sine-wave response function is:

$$Y(f) = (1 + 2\pi Df) \exp(-2\pi Df) \\ = (1 + 2\pi f/AF) \exp(-2\pi f/AF)$$

Generalized in terms of F , these functions are shown as the full-line curves of Figs. 1 and 2.

Comparing the curves in Fig. 1, it will be seen that the fourth-power cosine function is closely similar to the other in the region of the 'skirts', but it has the desirable property of being less-sharply peaked and there is no central discontinuity. The related features in Fig. 2 are the similarity at the lower frequencies and the more-rapid fall at the higher frequencies.

For describing line-spread functions in general, the half-intensity width, W , is often a useful parameter. In symmetrical functions, W is defined by $B(W/2) = 0.5$ whence, for the fourth-power cosine function:

$$W = 0.3438/F = 1.2872D$$

Taking a medium-speed panchromatic film as an example, it is believed that W might typically be 15μ , whence $F = 23$ lines/mm. and $D = 12\mu$. A fair approximation to the subjective resolving power determined with a high-contrast target is often given by $1/W$; this is 67 lines/mm. in the example.

If the proposed function proves in practice to be a good model, its relation with the well-known $\cos^4\theta$ law of off-axis illumination in an optical imaging system will be of interest. However, whether or not the θ of that law can be identified with the $\tan^{-1}(x/D)$ of the expression for $B(x)$ first given, it may possibly be significant that the distance D appears to be about equal to the emulsion thickness.

N. W. LEWIS

Post Office Research Station,
Dollis Hill,
London, N.W.2.

¹ Frieser, H., *Phot. Korr.*, **91**, 69 (1955); **92**, 51, 133 (1956).

² Ingelstam, E., et al., *J. Opt. Soc. Amer.*, **46**, 707 (1956).

³ Perrin, F. H., *J. Soc. Motion Picture Televis. Eng.*, **69**, 151, 239 (1960).