

APPENDIX A

Value of the Constant Brightness Difference Rule

Though the maintenance of a constant brightness difference, whatever the numeric value of the contrast, does not give the best results, in the sense of minimizing the difference of performance obtained with different contrasts, it is clear that it has certain merits. In the first place, it ensures that tasks presenting the same contrast but involving different pairs of reflection factors will always present the same physical brightnesses. Thus sewing on white cloth with white thread, or on black cloth with black thread, are tasks which may involve the same order of contrast but, with the same illumination, will present very different brightnesses, and are known by experience to differ in difficulty. The objective difference between these tasks will evidently be removed by providing, for each, illuminations which differ in the ratio $\left(\frac{\rho_1 - \rho_2}{\rho_3 - \rho_4}\right)$, where ρ_1, ρ_2 , are the reflection factors of the white, and ρ_3, ρ_4 , those of the black materials. In other cases, where tasks differ also relative difference of reflection factors, the mean of their brightnesses will vary inverse with their reflection factor difference at illuminations which give them equal brightness difference. This lessens the difference of performance with different contrasts that occur when equal brightness difference is not secured. Referring to Figs. 8a, 8b and 8c, showing the relation between relative performance and $(B_1 - B_2)$, it is evident that, for the low value of $\left(\frac{\rho_1 - \rho_2}{\rho_3}\right)$ considered, values of $(B_1 - B_2)$, different for each size, can be found at which relative performance has any desired value and is the same for each size.

At these values of $(B_1 - B_2)$ relative performance may differ with higher values of $\left(\frac{\rho_1 - \rho_2}{\rho_3}\right)$ but only in excess of the chosen value. If a high value of relative performance is chosen

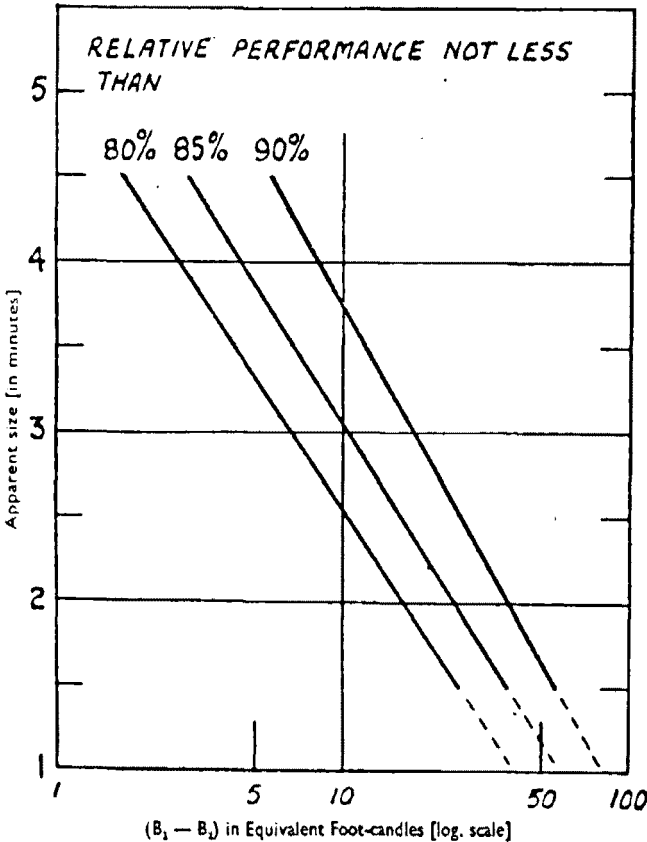


FIG. 10.

the necessary values of $(B_1 - B_2)$ lie on, or very close to, a straight line relating size with the logarithm of $(B_1 - B_2)$. Thus, an empirical formula can be derived for calculating the brightness difference necessary to give *not less* than a specified relative performance with visual tasks involving any size and $\left(\frac{\rho_1 - \rho_2}{\rho_1}\right)$ value within the range of these variables considered.

The relation between size and $(B_1 - B_2)$ for three minimum standards of relative performance is shown in Fig. 10. The equations are as follows:—

Relative performance—with any $\left(\frac{\rho_1 - \rho_2}{\rho_1}\right)$ value—not less than—

- (1) 80 per cent. . . . $\log_{10} (B_1 - B_2) = 1.99 - 0.39 S$
 or $(B_1 - B_2) = 10^{1.99 - 0.39 S}$ e.f.c.
- (2) 85 per cent. . . . $\log_{10} (B_1 - B_2) = 2.12 - 0.37 S$
 or $(B_1 - B_2) = 10^{2.12 - 0.37 S}$ e.f.c.
- (3) 90 per cent. . . . $\log_{10} (B_1 - B_2) = 2.23 - 0.33 S$
 or $(B_1 - B_2) = 10^{2.23 - 0.33 S}$ e.f.c.

where S = visual size in minutes of arc.

The corresponding values of relative performance for all values of $\left(\frac{\rho_1 - \rho_2}{\rho_1}\right)$ used in the second investigation are given in Table V.

The illumination E required to provide the necessary brightness difference is a function only of $(\rho_1 - \rho_2)$, hence

$$E = \frac{(B_1 - B_2) \text{ e.f.c.}}{(\rho_1 - \rho_2)} \text{ foot-candles.}$$

and

$$E = 10^{K - 4S} \text{ e.f.c.} \text{ foot-candles.}$$

Between the limiting values of size and $(\rho_1 - \rho_2)$ here considered the brightness difference values found from equation (1) correspond with illuminations which range from $\frac{1.718}{0.87} = 1.975$ ft./cs. to $\frac{25.41}{0.25} = 101.6$ ft./cs.

But the lowest order of contrast used, viz. $:- \frac{\rho_1 - \rho_2}{\rho_1} = 0.28$, might be obtained with a value of $(\rho_1 - \rho_2)$ only one-tenth of 0.25, i.e. by means of reflection factors $\rho_1 = 0.09$, $\rho_2 = 0.065$. In this case, for a size of 1.5 mins., $E = \left(\frac{25.41}{0.025}\right) = 1,016$ ft./cs. This value may exceed that required for a relative performance of 100 per cent. with many practical tasks involving this size if they are not purely visual tasks. It is only a practicable value for local artificial lighting.

TABLE V

R.P. not less than	Size in minutes	$(B_1 - B_2)$ e.f.c.	$\left(\frac{\rho_1 - \rho_2}{\rho_1}\right)$				$\left(\frac{\rho_2 - \rho_1}{\rho_2}\right)$
			0.97	0.56	0.39	0.28	0.25
80	4.5	1.718	94.5	85.0	81.0	80.0	96.5
	3.0	6.607	95.0	91.0	87.5	80.5	
	1.5	25.41	93.5	81.0	80.0	82.0	
85	4.5	2.851	95.5	89.0	86.0	85.0	97.7
	3.0	10.23	96.0	93.5	90.0	85.0	
	1.5	36.73	95.5	86.0	85.0	87.0	
90	4.5	6.095	97.0	93.0	92.0	91.0	98.7
	3.0	19.05	98.0	96.0	93.0	90.0	
	1.5	59.57	97.0	91.0	90.0	93.0	

It is evident, of course, and will be seen on inspection of Table V, that the higher the standard of relative performance, the closer will be the approximation to this standard with any contrast when it presents the given brightness difference.

Other forms of the relation between size and brightness difference can be derived from the data obtained, which will be valid for other criteria of relative performance. For example, taking the values of brightness difference at which exactly, instead of not, less than, 90 per cent. R.P. is obtained with each contrast, it is found that, for each size, the

mean of these values lies close to a straight line relating the logarithm of size with the logarithm of brightness difference. The equation to this line is, $\log. BD = 2 - (2.33 \log. S)$ or $BD = \frac{10^2}{S^{2.33}}$, where $S =$ visual size in minutes of arc.

The calculated value of brightness difference appropriate to each size is as follows :—

Size	Constant brightness difference
4.5 mins.	3.0 e.f.c.
3.0 mins.	7.7 e.f.c.
1.5 mins.	38.9 e.f.c.

and the mean deviation of these values from the corresponding means of the observed values is ± 7.5 per cent.

APPENDIX B

Variation of Mean Brightness with $\left(\frac{B_1 - B_2}{B_1}\right)$ for Unit Brightness Difference

In Fig. 11 the relation is shown between $\left(\frac{B_1 - B_2}{B_1}\right)$ and the mean of the brightnesses involved when their difference is constant. As stated in the report, the illumination required to give constant brightness difference may be the same for different contrasts, or, alternatively, different illuminations may be required either for different contrasts or for the same contrast, according to the reflection factors involved. But whether the same or different illuminations are required, the mean of the brightnesses involved will differ as shown, being always greater for the poorer contrast but constant for the same contrast whatever the values of its reflection factors.

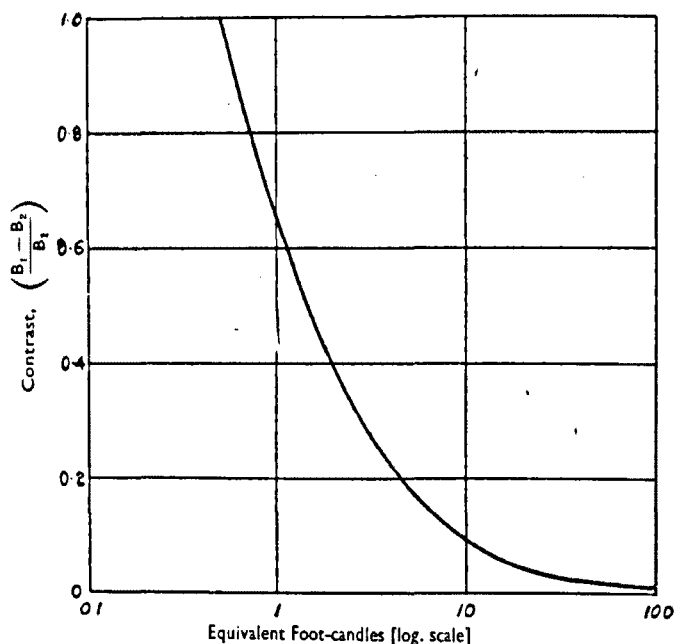


FIG. 11.—Relation between contrast, $\left(\frac{B_1 - B_2}{B_1}\right)$, and the mean of the brightnesses required to present a constant brightness difference of 1 e.f.c.

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