ing to be equivalent). It seems an unnecessary complication to formalize this with new symbols and nomenclature which do little more than obscure the physical basis of the phenomena.

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The Multiple-Film Technique: the Effect of Angle of Incidence on the Correlating Factor

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It is noted that the correlating factor for the multiple-film technique depends on the angle of incidence of the diffracted beam on the film and so has not the same value for all reflexions. The variation of the factor is discussed in detail for oscillation photographs recorded on cylindrical films with the axis of the cylinder as the axis of rotation of the crystal, the factor being constant for all reflexions on the same layer line. Methods of using spots on all layer lines, in an averaging process for finding the factor for each layer, are suggested. The treatment is also applicable to the method of interleaving films with metal foil when using Mo K radiation.

The multiple-film technique first described by Robertson (1943) is nowadays widely used for the measurement of intensities by the visual method. The intensities of the spots on the second and succeeding films are related to those of the spots on the first film by a correlating factor for which Robertson gave a value of about 2, for Cu $K\alpha$ radiation at normal incidence. The variation, with angle of incidence of the diffracted beam on the film, of absorption and photographic action in a single film, as applying to intensity measurements, has been considered by Cox & Shaw (1930) and, more recently, by Whittaker (1953). Whereas the variation of photographic action does not affect the multiple-film technique, the variation of absorption does, causing a change in the correlating factor.*

To discuss this change, let us consider an oscillation photograph recorded on cylindrical films with the axis of the cylinder as the axis of rotation of the crystal. If I_0 is the intensity recorded on the first (i.e. nearest to crystal) film and I that on the second (I_0 and I being within the range of reasonably accurate intensity measurement, so that reflexions giving either very strong or imperceptible blackening of

either film must be neglected), we have, using double emulsion films,

$$(I/I_0)_n = \exp\left[-(2\mu_e t_e + \mu_b t_b)\sec\nu_n\right], \quad (1)$$

where the subscript n denotes the nth layer line; μ_e and μ_b are the linear absorption coefficients of the emulsion and base respectively; t_e and t_b are the thicknesses of one side of the emulsion and of the base respectively; and ν_n is the inclination of the diffracted beam to the equatorial layer.

For the zero layer,

$$(I/I_0)_0 = \exp\left[-(2\mu_e t_e + \mu_b t_b)\right], \quad (2)$$

and thus, inverting,

$$(I_0/I)_n = (I_0/I)_0^{\sec\nu_n} = (I_0/I)_0^\alpha, \quad (3)$$

where $\alpha = \sec\nu_n = (1-\zeta^2)^{-\frac{1}{2}}$.

Let $(I_0/I)_n = R_n$, the correlating factor for the nth layer.

Then
$$R_n = R_0^\alpha. \quad (4)$$

The effect is considerable for high layer lines, as α increases to 1·7 when $\zeta = 0·8$, and is by no means negligible even for lower layers. If the intensity measurements are to be at all accurate, it must be taken into account.

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* *Note added in proof, 24 September* 1953.—Since the submission of this paper, this effect has been mentioned by Qurashi (1953).

Table 1. *Values of β_n as function of R_0 and ζ*

ζ \ $R_0 =$	2·1	2·2	2·3	2·4	2·5	2·6	Average β_n
0·0	1	1	1	1	1	1	1
0·1	1·004	1·004	1·004	1·004	1·005	1·005	1·00
0·2	1·016	1·017	1·018	1·019	1·019	1·020	1·02
0·3	1·036	1·039	1·041	1·043	1·045	1·047	1·04±0·01
0·4	1·070	1·074	1·079	1·083	1·087	1·091	1·08±0·01
0·5	1·122	1·130	1·138	1·145	1·153	1·160	1·14±0·02
0·6	1·204	1·218	1·231	1·245	1·257	1·270	1·24±0·04
0·7	1·346	1·371	1·395	1·419	1·443	1·466	1·41±0·06
0·8	1·640	1·692	1·743	1·793	1·843	1·891	1·77±0·13

We wish to know R_n for each layer line and we can calculate it from R_0 since we know α. To find R_0, it is best to average the measured ratios for a large number of spots distributed over the whole film. However, the measured ratios give $R_0, R_1, R_2, \ldots$, and, in order to average them, they must be reduced to the corresponding R_0. There are several ways of accomplishing this:

(a) R_n can be found for each layer and the αth root taken. The values of $\sqrt[\alpha]{Rn}$ ($= R_0$), suitably weighted for the number and intensities of spots used for each, can then be averaged. This involves tedious calculation, but it must be used where method (c) described below fails.

(b) Graphical methods, such as plots of R_n against ζ, $\log R_n$ against α and $\log \log R_n$ against $\log \alpha$, suggest themselves but are found to be inaccurate in practice.

(c) This method is of special applicability to the case of Cu $K\alpha$ radiation for which R_0 is about 2·3 for Ilford Industrial G, double-emulsion X-ray film. When R_0 has such a value, which is small compared with that for radiations of longer wavelength (and one would probably not use the multiple-film technique for long-wavelength radiation because of the high correlating factor), we may use

$$R_n = \beta_n R_0 , \qquad (5)$$

where β_n varies with n but is almost independent of R_0. This is only an empirical relation but it is true for the range of values of R_0 encountered. β_n can be calculated theoretically for various values of R_0 by combining equations (4) and (5), whence

$$\beta_n = R_0^{\alpha-1} . \qquad (6)$$

Some values of β_n are given in Table 1.

From this table, it is seen that β_n may be considered to be independent of R_0, the greatest variation (when $\zeta = 0·8$) being only 14%. From (5),

$$R_0 = \frac{R_n}{\beta_n} = \frac{1}{\beta_n}\left(\frac{I_0}{I}\right)_n \qquad (7)$$

and, averaging for all spots on the film,

$$R_0 = \frac{\Sigma(I_0/\beta_n)}{\Sigma I} \qquad (8)$$

$$= \frac{\Sigma I_0}{\Sigma \beta_n I} . \qquad (9)$$

It is preferable to use (8) rather than (9), since (8) gives less weight in averaging to the measurements for which β_n is high. The high values of β_n (for high layer lines) are not known so precisely because (a) they depend to a greater degree on the value of R_0 than do the lower values, and (b) the ζ values, and consequently the β_n's, for high layer lines are known less accurately than for lower layers.

The procedure for finding R_0 by this method is:

(i) I_0 and I are measured for each reflexion, within the limits previously defined;

(ii) for each layer in turn, the I_0 values are totalled and the sum is divided by the 'average β_n' appropriate to that ζ value, giving $(\Sigma I_0)_n/\beta_n$ for each layer;

(iii) the $(\Sigma I_0)_n/\beta_n$ values for all layers are totalled, giving $\Sigma(I_0/\beta_n)$;

(iv) all the I values are totalled, giving ΣI;

(v) and, finally, R_0 is calculated using (8).

When R_0 has been found, $R_1, R_2, R_3, \ldots$ can be calculated using (5) with the value of β_n appropriate to n (or ζ) and to *this* R_0.

The effect discussed above also operates when films are interleaved with metal foils for use with Mo K radiation and the methods given are still applicable. When the equi-inclination Weissenberg method (or any other method in which the layers are recorded separately) is used, the correlating factor will be constant over any one pair of films (for one layer) but will vary from layer to layer. Consequently one cannot assume *one* average value of the factor for all layers.

When other ways of supporting the photographic films are used, the correlating factor will vary with ξ as well as with ζ and the treatment will be more complex.

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