Studies in Photographic Sensitivity, Part III.

Sensitizing Action of Previous Exposure to a Dim Light

By

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Abstract

It is well known that faint spectral lines can successfully be developed out when a photographic plate is previously exposed to a dim light. Systematic studies of this phenomenon were carried out, and the following facts were found:— (1) Certain photographic plates thus treated have greater density than that corresponding to the sum of the two exposures, that is, the characteristic curve of a fogged plate has smaller inertia than that of an untreated plate, even when corrections of the fog density are applied to densities of the treated plate. (2) Fogging made before the main exposure is more effective than that made after the main exposure. (3) This sensitizing action gradually decreases with increases in the time between the two exposures. (4) The sensitizing action of fogging due to a red light is greatest, that due to a yellow light is medium, and that due to a violet light is least. (5) This sensitizing action of previous fogging is marked in panchromatic plates but is slight in ordinary plates.

Introduction

In order to get a developable image with noticeable density a certain amount of light energy should be given to a photographic plate, and therefore to intensify faint spectral lines in a photographic plate preliminary exposure to a dim light is required.

This method was used by Wood[1] to photograph faint spectra. He considered that a small exposure is sufficient to produce an appreciable

1 Astrophys. J.; **27**, 379 (1908)

image if the plate has previously been exposed to the toe point in the characteristic curve, because the latter curve suddenly becomes steeper from that point, and that the auxiliary exposure acts equally whether given before or after the main exposure.

This method was generally followed by many investigators in spectroscopic work.

The present writer, however, found that in certain plates the image developed after such treatment always had greater density than that corresponding to the sum of the two exposures, that is, the preliminary exposure to a faint light increases the sensitivity of the plate even when the fog correction is applied.

Fog Correction

Now let the density produced by a main exposure (E_o) be D_o, and that due to an auxiliary exposure (E_f) or fogging be D_f, then the formula of the density growth is given by Elder as follows.

$$\left.\begin{aligned} D_o &= D_m(1-e^{-KE_o}) \\ D_f &= D_m(1-e^{-K'E_f}) \end{aligned}\right\} \quad \cdots\cdots (1)$$

where D_m is the maximum density of the plate, and KK' are constants.

The amount of silver bromide grains in an unexposed plate is proportional to D_m, and that of unaffected silver bromide grains in a plate previously exposed to a fogging light is proportional to (D_m-D_f). Accordingly, if the two exposures act cumulatively, the resultant density of the plate is given by the equation.

$$\begin{aligned} D_s &= D_m(1-e^{-K'E_f})+(D_m-D_f)(1-e^{-KE_o}) \\ &= D_o+D_f-\frac{D_oD_f}{D_m} \quad \cdots\cdots (2) \end{aligned}$$

The same equation as the above is also obtained in the case where a fogging exposure is given after a main exposure.

Consequently the fog correction which should be subtracted from an apparent density becomes

$$D_c = D_s - D_o = D_f\left(\frac{D_m-D_o}{D_m}\right) \quad \cdots\cdots (3)$$

All $D's$ in the above equation denote the densities which may be obtained by complete development. But the velocity equation of development is given by Nietz[1] as follows :—

$$D_t = D_m(1 - e^{-\beta \log t/t_0}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

D_t denoting the density of a negative obtained by development for t minutes, D_m the corresponding density obtained by a full development, t_o the initial period of apparent inactivity, and β a constant. If we assume that the velocity factor β is the same for every exposure in the present experiments, the density obtained by a finite time development will be proportional to the density obtained by a complete development, and the densities in the equation (3) will be replaced by the densities obtained by a finite development.

The equation (3) is also obtained even when another expression of density growth is used.

This formula for the fog correction is similar to that given by Wilsey[2] starting from the assumption that the fog over the image is proportional to the mass of unaffected silver bromide grains, and has been proved by many observers to be correct for chemical fog when their densities are below 0.5. In the case where a fog has been given by an exposure to a dim light, the characteristic curve of a photographic plate exposed only to H & D's sector photograph and that of a plate first fogged and then exposed must coincide, provided that the fog correction has been applied, according to (8), to densities of the treated plate. It was found in the following experiments that in panchromatic plates, such correction was generally not sufficient to give the correct result though in many ordinary plates this was found to be sufficient. This fact means that the two exposures do not act cumulatively.

Method of Experiment

Main exposures were made with the sector spectrograph used in the previous work.[3] Fogging exposure was given by a light, filtered or unfiltered, from a 4-volt miniature-lamp placed at a distance of two meters from the plate, in the latter case Wratten's monochromatic filters being used. Densities were measured by means of a Moll's microphotometer. The method of the development and other necessary precautions have been given already in the previous paper and these are omitted here.

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1 "Theory of Developement; "p. 165.
2 Phot. J.; **65** 454 (1925)
3 These Memoirs; **12**, 1 (1929)

The plate to be tested was cut into six parts, giving the four pieces necessary for one experiment, the two end strips being discarded. The first one was exposed to the sector spectrum without any treatment, next, the second piece was given the same exposure and then it and the third piece were given the fogging exposure simultaneously in a dark room, the latter being then exposed to the sector spectrum. The fourth piece was exposed only to the sector spectrum. Thus the third plate was given the auxiliary exposure before its main exposure, while in the second, this order was reversed. Thus the fog densities of these two plates were made to be equal, as the foggihg exposure given to the two plates was the same.

Results of the Experiments

Two characteristic curves of previously fogged plates are shown in fig. 1, I, II and III, the latter corrected for the fog density, while the former is

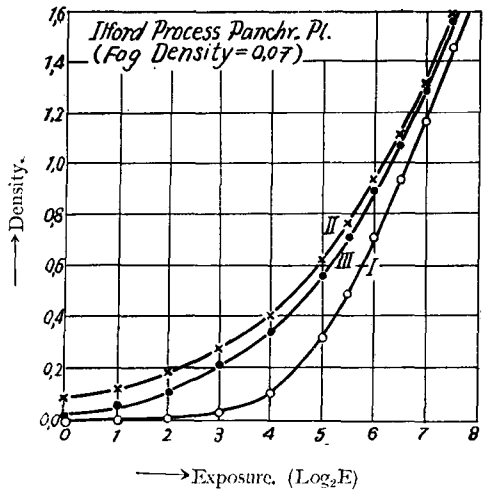


Fig. 1

Effect of previous fogging on a characteristic curve.

I The characteristic curve of the untreated plate.
II „ „ the treated plate without fog correction.
III „ „ „ corrected for the fog density.

not, I representing the corresponding curve of an untreated plate. As is seen from the figure the increase in density produced by the fogging was always greater than the fog density.

The similar results obtained for several kinds of plates are represented

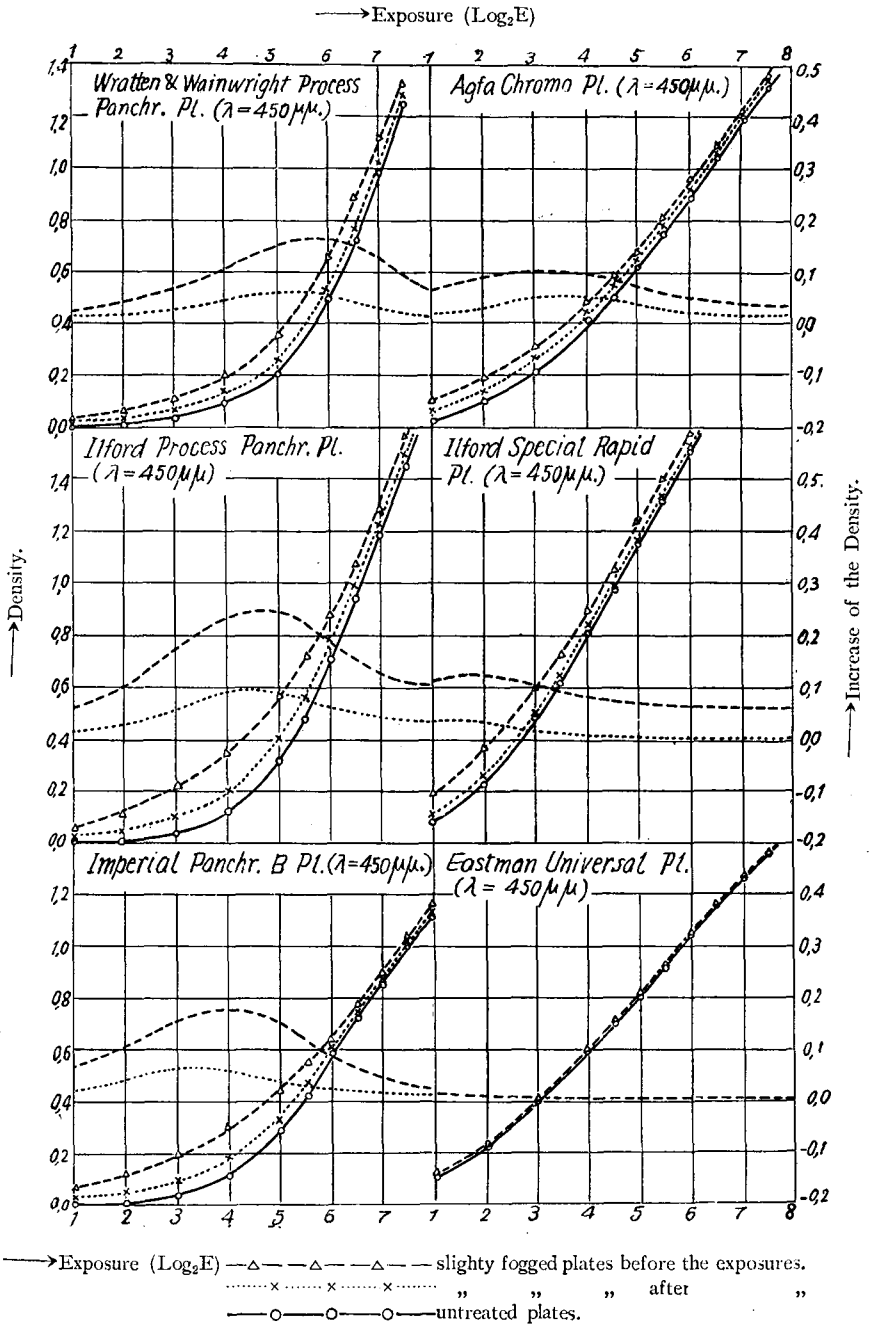


Fig. 2
Comparison of the characteristic curves of the slightly fogged plates with those of the untreated ones.

in fig. 2. The characteristic curves of untreated plates are shown in continuous lines, corresponding curves of previously exposed plates are represented in broken lines, and those of the plates to which the auxiliary exposure were given after the main exposure, in dotted lines. The increase in densities called forth by the fogging at various exposures are also represented with broken and dotted lines. White light was used for fogging throughout these experiments, and corrections for fog density were made according to the formula (8) mentioned above.

The inertia of untreared plates was always the greatest, and that of previously treated ones smallest, and the same is the case with contrast.

It may be said from these results that an auxiliary exposure to a dim light sensitizes a photographic plate in addition to its own blackening action and decreases its contrast, but in the case where the fogging exposure was given after the main exposure this effect is very small. This sensitizing action was marked for all panchromatic plates used in this experiment, but this action was small for a few kinds of orthochromatic and ordinary plates, while this action could not be found in Ilford Process, Imperial Process, Eastman Universal, Wellington Anti-screen plates, etc.

Colour of Fogging Light

Similar experiments were made with coloured lights. For this purpose the rays from the miniature-lamp were filtered through Wratten's monochromatic filters, No. 70 (red), No. 73 (yellow), and No. 76 (violet). The exposure to these fogging lights was adjusted to give equal fog densities for the lights of the three different colours, all these exposures being given before the main exposure.

Fig. 3 shows the effect of slight fogging given by the above mentioned coloured lights on the sensitivity of certain panchromatic plates for rays of various wave lengths, taking the increase of density as ordinate and wave length as abscissa. As the change in the inertia was generally small, the amounts of sensitization at various wave lengths are compared by means of the maximum increase in density. The sensitizing effect of fogging by the red light was always greatest, that by the yellow light medium, and that by the violet light least.

The sensitizing curve shown in Fig. 3 has a somewhat similar form to the sensitivity curve of the plate for each colour, and in each curve the amount of sensitization is great in the spectral regions of red and orange.

Plate I shows the sector spectra taken on the plates, one being un-

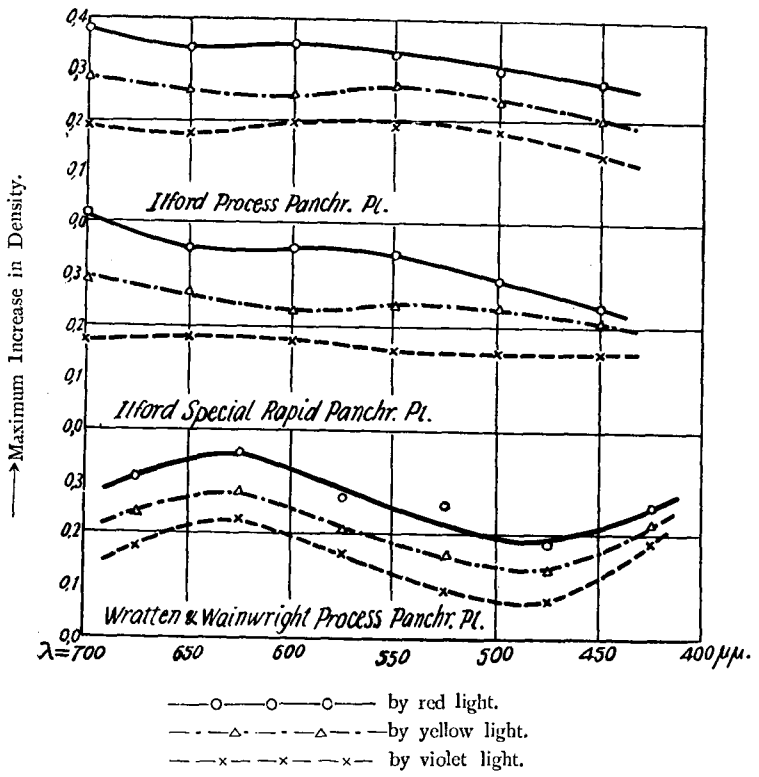


Fig. 3

Sensitizing Action of the Previous Fogging due to Monochromatic Lights.

treated and the other treated with red and violet lights separately. The back-ground of all these photographs is printed to give an equal blackening.

Fatigue of the Sensitizing Action

Fatigue of the sensitizing effect of previous exposure was examined by varying the interval between two exposures. This effect was greatest when the main exposure was made immediately after the fogging exposure, but gradually became smaller when the interval between the two exposures was lengthened. This is seen from figs. 4 and 5, the former representing the characteristic curves and ΔD-logE curves for the plate taken at various intervals after the fogging exposure, and the latter the decay of the maximum increase of density with time. This decay was very small for the first 2 hours, and then it became marked.

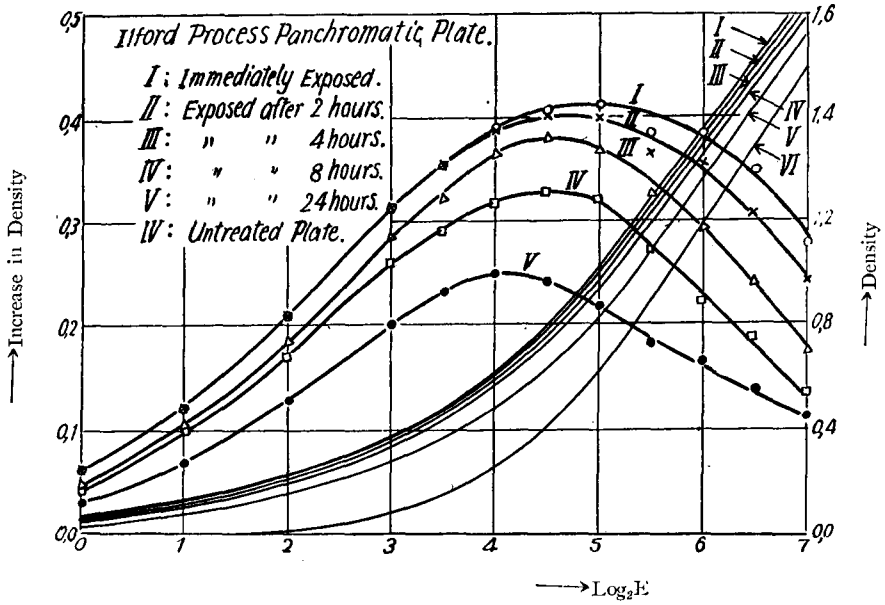


Fig.4

Fatigue of the sensitizing action of previous fogging

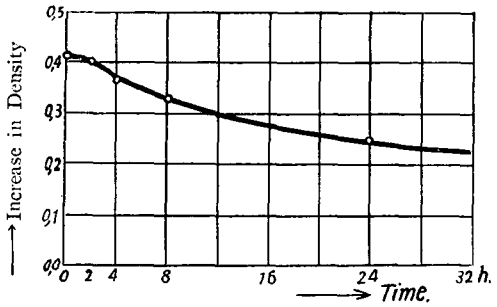


Fig.5

Fatigue of the sensitizing action

Effect of Varying the Fog Density

Next, the relation between the amount of sensitization caused by previous fogging and the fog density was studied. When the time of the fogging exposure is lengthened the fog density becomes greater and the

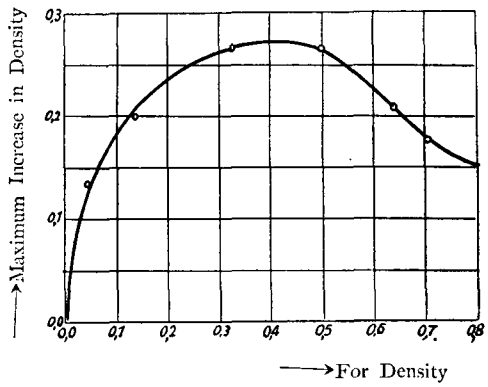


Fig.6

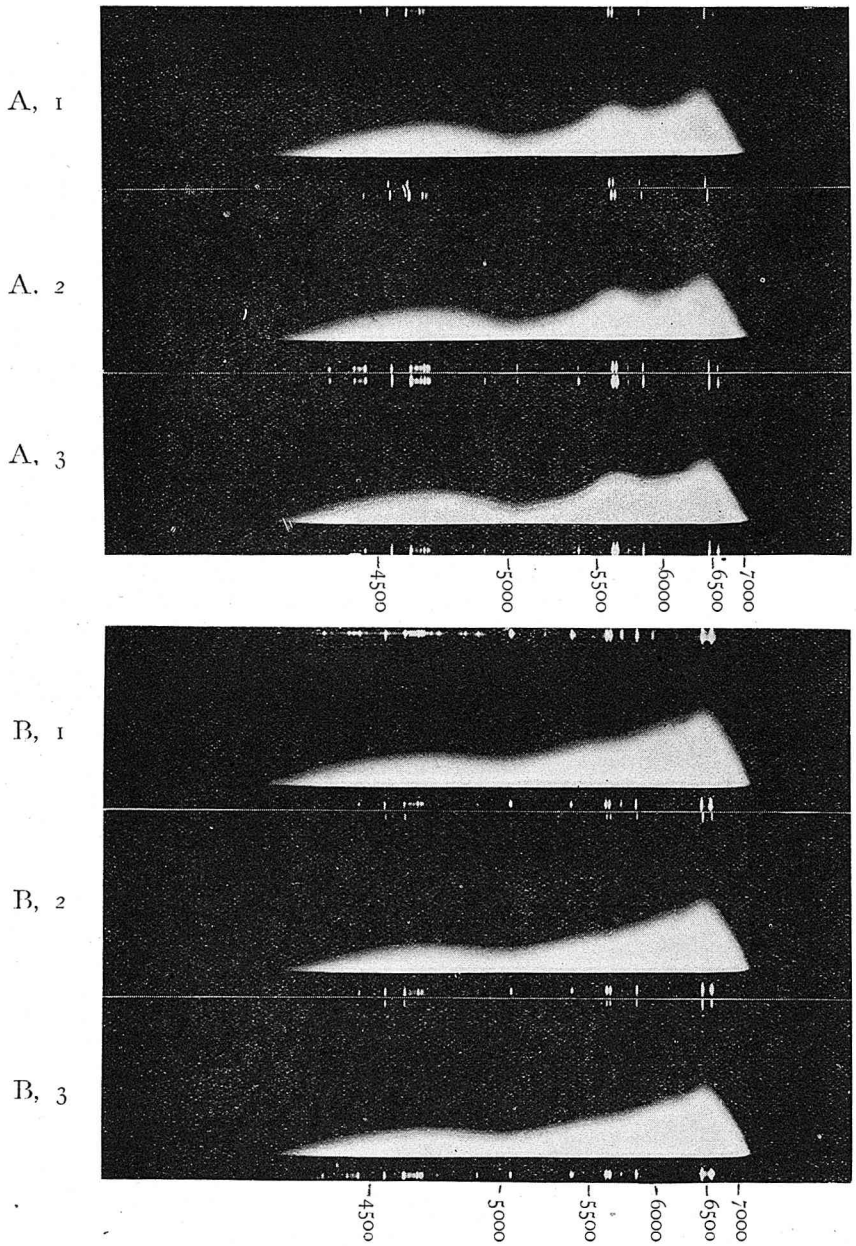
Showing the Relation between the Degree of Sensitizing Action and Fog Density

amount of sensitization is also increased, but it reaches a maximum at a certain density of the fog. This limiting density was about 0.4 for Ilford Special Rapid Panchromatic Plate, but after this was reached, the amount of sensitization was gradually decreased. Fig. 6 represents the relation between the maximum increase in density and the fog density.

It seems to the present writer that the sensitizing effects of a previous fogging is probably caused by the action of optical sensitizers.

In conclusion the author wishes to express his sincere thanks to Prof. M. Kimura for his valuable advice and the great interest he has taken in this investigation, and also to President T. Maruyama of the Konan College for his good offices.

Plate I



1. Sector spectrum taken with a previously fogged plate by red light.
2. „ „ „ „ „ „ „ by violet light.
3. „ „ „ with an untreated plate.

A. Wratten & Wainwright Process Panchromatic Plate.
B. Ilford Process Panchromatic Plate.