PRESSURE EFFECT ON PHOTOGRAPHIC SENSITIVITY

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Abstract

The effect of pressure on photographic sensitivity is discussed on the experimental basis that the quantity E/E_c, where E is the illumination actually used when the photographic emulsion is under pressure, and E_e the illumination which would be required to produce the same optical density when the emulsion is under no pressure, is a function of pressure only and that for pressures greater than a certain value, E/E_e becomes a linear function of the pressure.

Experiments have been done to investigate the effect in the region of reversal. It was found that the effect of pressure is always to reduce the photographic sensitivity no matter whether it is tried in the region of normal or over exposures or in the region of reversal. Experiments using monochromatic radiations were also performed which established the fact that the effect of pressure diminishes with wave-lengths. A tentative relations between this effect and the absorption properties of the photographic sensitive layer is suggested. The effect was found to vary widely with different films.

Finally some applications of this effect have been pointed out.

Introduction

The application of pressure to a photographic emulsion during exposure prevents the formation of latent image to a great extent and thus reduces its sensitivity. The effect of pressure is temporary, for if the exposure is made, even immediately, after the removal of the pressure, there is but very slight effect left in the film.

To characterize this effect, we have introduced a quantity E/E_c, E_e being the illumination which would produce, on an emulsion without being subject to any pressure, the same optical density as that produced by illumination E on the same emulsion under a pressure p with equal time of exposure. E_c is always less than E and may be called in photography the effective illumination of E under pressure p.

Two series of exposures, one subject to no pressure and the other under a pressure p, were taken by varying illuminations only, and the characteristic curves are plotted in figure 1. The curve d-log E corresponds to the series of exposures without being subject to any pressure, and the curve d'-log E to the series of exposures under a pressure p. These two curves are nearly parallel to each other and can be brought into coincidence by a simple translation parallel to the axis of log E. It is therefore this translation that characterizes the photo-

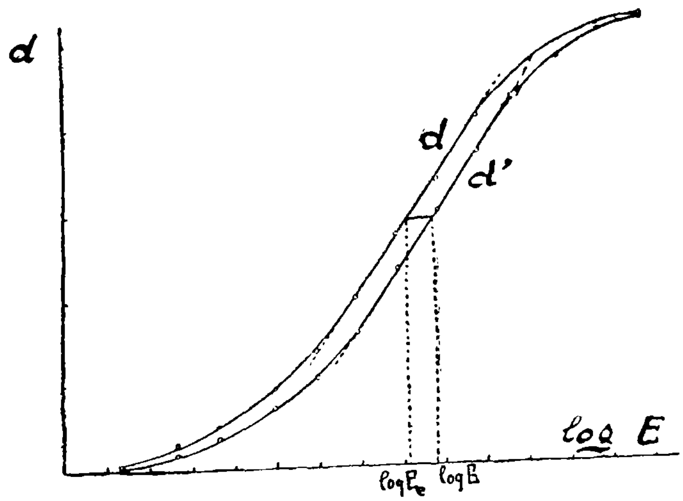


Fig. 1

graphic effect of pressure. We have experimentally established that the quantity E/E_c is a function of pressure only[1] and that for p greater than a certain value, the ratio E/E_c is a linear function of the pressure p.

(1) Ny Tsi-Zé et Tsien Ling-Chao, Comptes rendus, 194, 1932, p. 1644.

Pressure Effect in the Region of Reversal

It is a well known fact that the density of a photographic plate does not increase indefinitely with exposure. There is reversal. What will then be the pressure effect on photographic sensitivity in the region of reversal?

If the parallelism of the two curves in figure 1 could be extrapolated into the region of reversal, they would intersect in certain point, and after the point of intersection, the curve d'-log E would lie above the curve d-log E. This amounts to say that the effect of pressure would increase the sensitivity of the plate for excessive exposures, contrary to what happens in the regions of under, normal and over exposures.

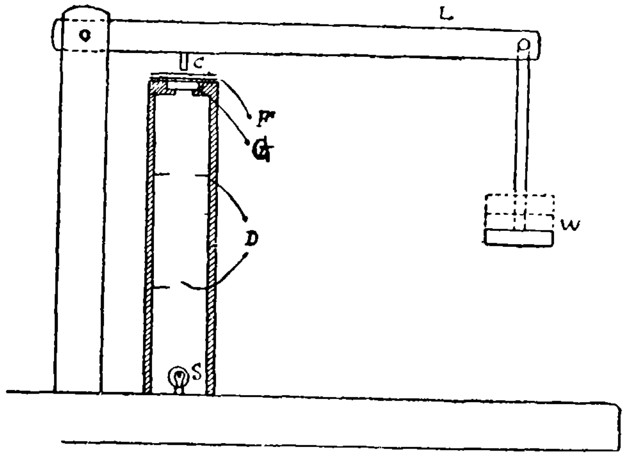


Fig. 2

It appears therefore quite interesting to investigate the pressure effect on photographic sensitivity in the region of reversal. With the experimental arrangement (Fig. 2) previously described and the same procedure[2] we have only to prolong the exposure.

The pressure was applied by means of a lever L and weights W, which forced the well polished base of a steel cylinder

(2) Ny Tsi-Zé et Tsien Ling-Chao, Science et Industries Photographiques, 2 série, t. 4, 1933 p. 1.

C, against the back of the photographic film F. The film F was supported by a glass plate G 5mm. thick. The source of light S, was a 6 volts Philips lamp, the filament of which being 64cm from the film. The light was confined to a beam by means of two diaphragms D. The beam of light was circular in cross section having a diameter of 14 mm, while the base of the cylinder had only a diameter of 5 mm and was approximately concentric with the beam.

On one film, several exposures were made under the same pressure on varying the time of exposure. The densities at the center and the rim of each photographic image were measured with a Moll microphotometer. The results given in the following table are average values of two or three determinations referred to Zeiss-Ikon anti-halo orthochromatic film under a pressure of 462 kg/cm^2.

Table I.

Time of exposure t	Rim density d	Center density d'
$\frac{1}{100}$ sec	0.02	0.01
$\frac{1}{50}$	0.08	0.045
$\frac{1}{25}$	0.205	0.12
$\frac{1}{10}$	0.515	0.335
$\frac{1}{5}$	0.725	0.55
$\frac{1}{2}$	1.04	0.85
1	1.28	1.08
2	1.47	1.29
4	1.64	1.53
8	1.78	1.71
16	1.86	1.79
32	1.92	1.88
1 min 4 sec	1.96	1.91
2 8	1.98	1.95

(*Continued on the next page*)

Time of exposure				Rim density	Center density
	4	16		1.96	1.91
	8	32		1.90	1.82
	17	4		1.86	1.78
	34	8		1.83	1.68
1 hr	8 min	16	sec	1.80	1.63
2	16	32		1.70	1.57
4	33	4		1.69	1.54

Reversal is seen to commence at the points of maximum densities $d=1.98$ and $d'=1.95$ respectively. The center density d' under pressure is always less than the corresponding rim density d subject to no pressure. The effect of pressure is therefore always to reduce the photographic sensitivity of the film.

Plotting log t as abscissae and d and d' as ordinates, we have the two characteristic curves (Fig. 3) of the film corresponding to no pressure and a pressure of 462 kg/cm^2 respectively. The difference of $d-d'$ is even greater in the region of reversal than that corresponding to the same density d in the region of over or normal exposures.

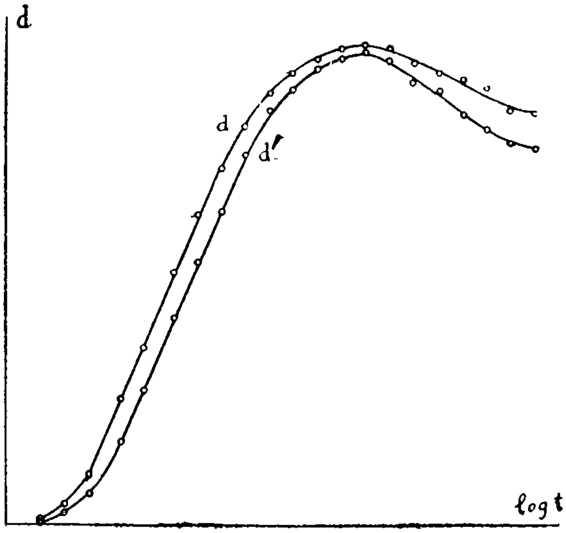


Fig. 3

Pressure Effect with Monochromatic Radiations

We have shown[3] that the effect of pressure on the photographic sensitivity varies very much with the radiations used. It is greater for radiations of long wave-lengths than those of short wave-lengths. To investigate this effect with monochromatic radiations of visible and ultraviolet light, a quartz mercury lamp was used.

The light was projected by a quartz condenser C, on the slit of a Leiss monochromator,[4] which is schematically repre-

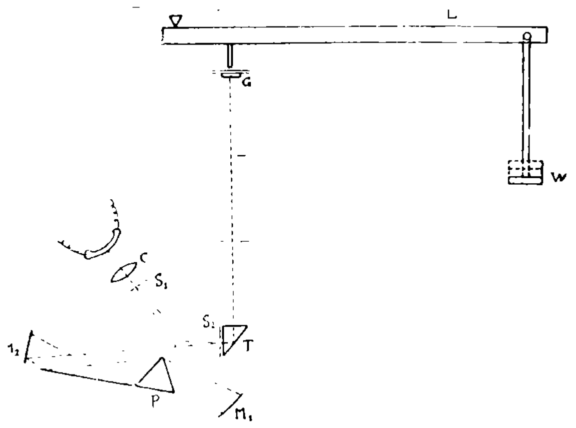


Fig. 4

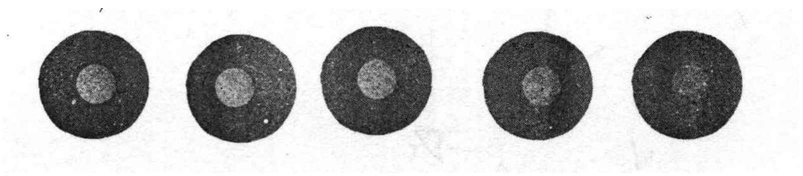
sented in figure 4. The light from the slit S_1, rendered parallel by the spherical mirror M_1, passes through a Cornu prism P in minimum deviation, is reflected by a Wadsworth plan mirror, and finally converged by a second spherical mirror M_2 on the slit S_2. On rotating, as a whole, the prism and the mirror which remains always parallel to the base of the prism, any line of the mercury lamp can be brought before the slit S_2. The beam of monochromatic light through S_2 is then sent vertically into the apparatus in figure 2 by a quartz prism of total reflection T. The plate G supporting the film, is, of course, also of quartz.

(3) Ny Tsi-Zé et Tsien Ling-Chao, Comptes rendus, 196, 1933, p. 107.

(4) C. Leiss, Zeit. fur Phys., 72, 1931, p. 822.

The experiment was performed on one film, either with the same pressure but using different radiations, or with the same radiation but using different pressures. For a certain radiation and one given pressure, five exposures of equal time were always made, varying the intensity of illumination by inserting in the path of light some screens, consisting of exposed and developed photographic sensitive layer between two quartz plates, whose densities had been previously calibrated.

The measurement of the densities at the center and the rim of the photographic images permits to trace the two curves d-log E and d'-log E. The translation parallel to the axis of abscissae bringing about the coincidence of the curve d with the curve d' measures the quantity log $\frac{E}{E_e}$ and consequently the ratio E/E_e.



5791 } 5770 } 5461 4917 4358 4047 Å

Fig. 5.—Photographic effect of pressure with different radiations of mercury arc for the same pressure of 970 kg/cm².

The time of exposure varied from one to fifteen minutes according to the different intensities of the mercury lines. The data given in the following table are for Zeiss-Ikon orthochromatic film.

Tables II.

	E/E_e							
Pressure p	5770 } 5791 }	5461.	4917.	4358.	4047.	3655.	3341.	3131. Å
81,3 kg/cm² .	1,77	1,60	1,51	1,14	1,02			
208	1,97	1,77	1,67	1,20	1,06			
462	2,15	1,98	1,87	1,28	1,11	1,03		
716	2,31	2,14	2,00	1,35	1,15	1,05	1,03	
970	2,49	2,31	2,20	1,37	1,17	1,07	1,04	1,03
1224	2,64	2,40	2,30	1,40	1,19	1,09	1,05	1,04

The effect of pressure on photographic sensitivity varies therefore enormously with the wave-length of the radiation used. It diminishes with the wave-length. For the yellow or green light a pressure of less than hundred kilograms per square centimeter is sufficient to produce an important effect, while for the radiation 3131Å, we have to apply more thar thousand kilograms per square centimeter in order to make the effect just observable.

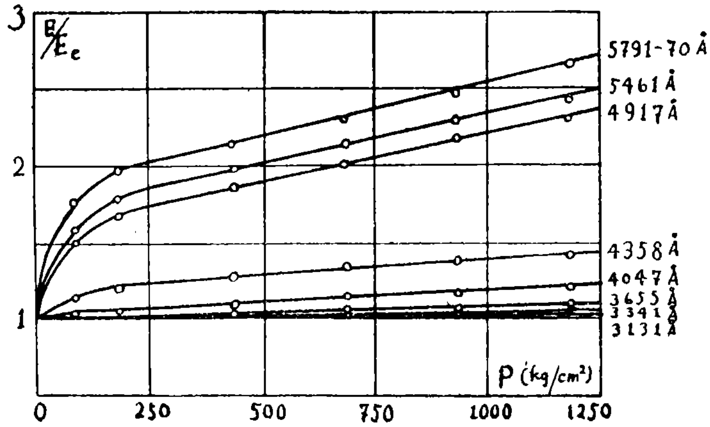


Fig. 6

In taking p as abscissae and E/E_e as ordinates, we obtain a family of curves (Fig. 6), which are rectilinear for p greater than 200 kg/cm² and can be represented by the equation:

$$E/E_e = a + \alpha\ p.$$

The different values of α corresponding to different radiations of the mercury arc are as follows:

Table III.

	5770 Å / 5791 Å	5461 A.	4917 Å.	4358 Å.	4047 Å.	3655 Å.	3341 Å.	3131 Å.
α	0,00067	0,00065	0,00057	0,00023	0,00013	0,00008	0,00004	0,00003

The variation of the pressure effect with wave-lengths is probably in close relation with the absorption properties of the photographic sensitive layer for different radiations. Fabry and Buisson[5] have, in fact, pointed out the great absorption of the sensitive layer for the ultra-violet. It follows that under the action of ultra-violet, the sensitive layer of a photographic plate or film is only superficially affected, while for the visible light, the photographic impression is produced throughout the whole thickness. We should therefore admit that the pressure would affect the internal levels of the layer but not the surface.

Pressure Effect with Different Films

The effect of pressure on photographic sensitivity may differ from one kind of film to another. It will be interesting to investigate this effect upon materials differing widely in characteristics. Besides the Zeiss-Ikon orthochromatic film, we have studied also Eastman super-speed portrait film and Agfa ultra-rapid isochrome film, which are readily found at our city. The results of these two films are shown in Fig. 7 and 8 respectively.

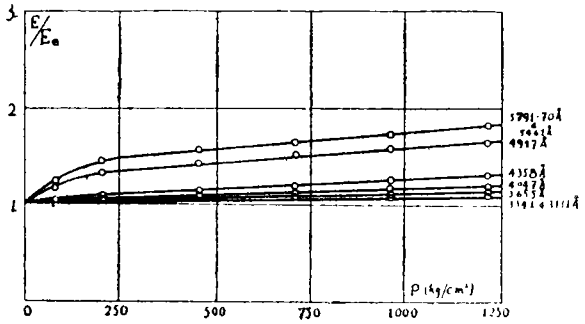


Fig. 7.—Eastman super-speed portrait film.

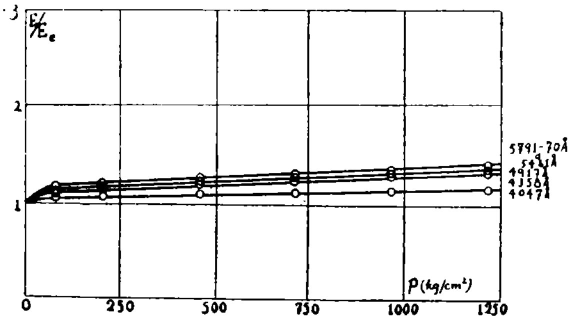


Fig. 8.—Agfa ultra-rapid isochrom film.

(5) Fabry et Buisson, Revue d'Optique, 3, 1924, p. 19.

It is seen that although all of these three are very rapid films, they differ very much in the effect of pressure on their sensitivity. The effect is comparatively very small for the Agfa isochrome film. The Eastman portrait film shows a less pronounced effect for the visible light than the Zeiss-Ikon orthochromatic film, but a greater effect in the ultra-violet.

A systematic study on photographic materials which are known to differ greatly in some respects should throw some light on the nature of the effect and this study is now in preparation.

Applications

This pressure effect on suitable materials may lead to some practical applications. For example in the apparatus of Fig. 2, if the base of the cylinder C, is not a plane, but a stamp, its mark will be faithfully impressioned, on applying it with force against the back of a photographic paper during exposure, as shown in Fig. 9.

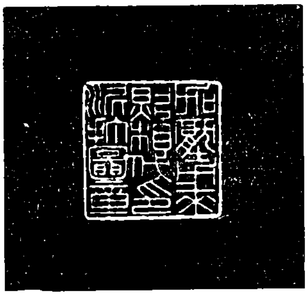


Fig. 9

The relation of the ratio E/E_c with the pressure p, once studied, may be inversely used to determine unknown pressure or its distribution.

壓力對於照相片感光性之影響

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當照相時,照相片子——映像紙,軟片,或玻璃板——被壓,則其感光性減弱,是爲照相的壓力效應。設E爲照相片子在壓力p下得光密度d所需之光照度,若片子不受壓力則用光照度E_e即可得此同一之光密度d,故E_e可稱在壓力p下E之有效照度。吾人實驗證明E/E_e爲壓力p之函數,當$p>200$ kg/cm²時,E/E_e與p成正比例。

此照相的壓力效應,與照相時所用光之顏色,極有關係。黃色光較綠色光爲顯,綠色光較藍色光紫色光爲顯至紫外光則幾無此效應。

又此效應之大小,隨各種照相片子而不同。就我們所研究的蔡愛斯伊康正色軟片,伊司門人像軟片,和矮克發等色軟片而論,以第一種爲最大第二種次之第三種爲最小。

這個效應,在實際上,或可有些應用。