The Effect of Evacuation of Photographic Plate on its Sensitivity.

By

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More than thirty years ago Carey Lea[1] noticed that a photographic plate is sensitive even to mechanical pressure; this is known as "pressure mark." Lea's results led me to think that it might be interesting to examine whether removal of absorbed gases from a sensitive film by evacuation has any blackening effect without exposing to light. The result was negative, but I found that after long developement under the ruby light there was less fog on the evacuated part than on the untreated. This led me to study the problem further and the results so far obtained are given below.

Preliminary experiments.

An india-rubber stopper of a proper size was taken and a small hole was made along its axis. One of the end surfaces was well cleaned, in order to bring it into close contact with the surface of the emulsion of a photographic plate. This was then placed on the photographic plate to be examined, and the remaining hole was connected to a Gaede's rotary pump by a glass tube, and thus a portion of the sensitive film was subjected to a reduced pressure of a few mm. for about 10 min. After the development, it was found that the blackening was greater on the part evacuated. Similar results were obtained when the exposure was made from the film side after the pressure had been raised to the atmospheric

1 Phil. Mag, V, **31**, 323 (1891).

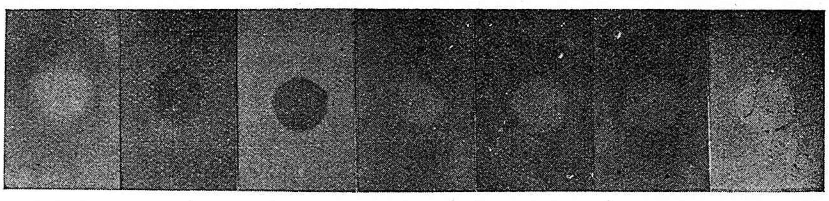
one, the amount of intensification being, however, small. But the contrast between the evacuated and the non evacuated portions was reversed when the plate was exposed not to white light but to the ruby light while the plate was in the developer. This result was very interesting and I thought that it was probably due to the difference in the colour of the light used for the fogging.

Guided by this idea, I repeated the experiments with monochromatic lights filtered through Wratten's monochromats, which consist of seven filters, namely α (deep red) β (orange red) γ (orange) δ (yellow) ε (green) η (blue) and θ (violet), and obtained the following results:—

Ordinary plates such as Ilford Special Rapid and Stanley were found to be sensitized by previous evacuation when they were exposed to the rays given by the filters θ, η, ε, and α, while the sensitivity of the evacuated parts was reduced when treated with the rays of β and γ, the process of evacuation, having no marked influence, however, when the plates were illuminated by the ray filtered through δ. A number of photographs given in Fig. 1, A show the effect of evacuation on Ilford Special Rapid plates when the exposures were made from the film side after the pressure had been restored, the circular images in the middle representing the hole in the india rubber. But if the exposures were made from the glass side while the plate was subjected to a partial vacuum the plates became sensitive to any of the rays, the degree of sensitization to the rays filtered through β and δ being very much smaller than the others.

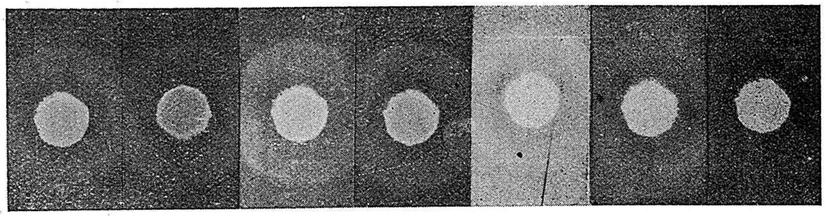
Panchromatic plates such as Seed and Ilford were always sensitized to any of the rays by the process of partial evacuation. Fig. 1, B shows the effect of evacuation upon the Seed Panchromatic plate, the exposure being made from the glass side during the evacuation. The central disk in each figure represents the evacuated part and the outer circular zone, the part covered by the india-rubber. The blackening in this part is also greater than in the uncovered part, and it may be supposed from this result that the high pressure upon the emulsion has also some effect on its sensitiveness.

Fig. 1, A



β γ δ ε η θ

Fig. 1, B



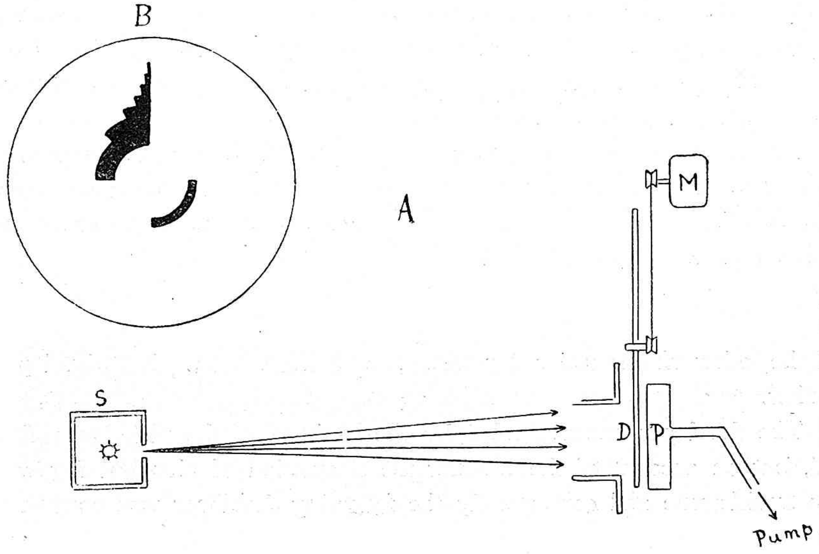
Although in the above experiments the plate was subjected to evacuation before the exposure was made, the present author has also examined the effect of evacuation on emulsions which had already been exposed, and found that the blackening of some plates such as Ilford Special Rapid and Stanley was reduced by the treatment, but that in some plates, such as Seed Panchromatic, it was increased.

From these preliminary experiments, the fact was ascertained that the reduction of the pressure to which a sensitive film is subjected has a certain influence on the blackening of the photographic image produced when it is exposed to coloured lights, and this led us further to the following quantitative experiments.

Apparatus.

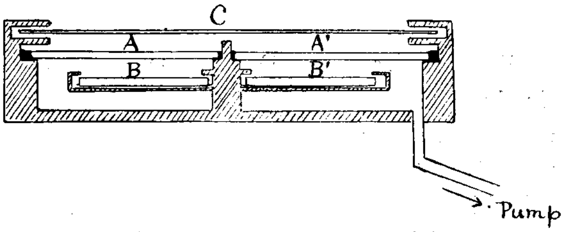
The arrangement of the apparatus used in this experiment is shown in Fig. 2.

Fig. 2.



P is a special plate holder designed for the purpose. This consisted of two parts, and on one part was kept at the atmospheric pressure while the pressure in the other was reduced to a desired value by connecting to a mercury pump, Fig. 3 shows the cross section of the plate holder made of brass.

Fig. 3.



A and A′ are glass plates which were cemented to the walls of the apparatus by means of Khotinsky cement B and B′ are photographic plates which were placed in their position through different slits made in one side of the holder, one of which was provided with an air tight cover. This plate holder was placed as in shown in Fig. 2 behind a Hunter and Driffield disk in which the central aperture being 180° while each successive angle was made equal to one-half of the preceding one as in Fig. 2, B. Thus exposures of a series in the ratio of 2^n, where n=0,1,2,3,4,5,6, & 7, were made on the photographic plate. As the light source a Mazda lamp (50 watts 100 volts), made of a milky glass was placed in front of the disk at a distance of about one meter from the plate. This was lighted by secondary batteries in order to keep the intensity of the light constant, and was enclosed in a box having a small rectangular aperture 3×3 mm^2. The sector wheel was rotated by mean of a motor at a rate of about 600 revolutions per minute.

In the following experiments the pressure in one part of the plate holder was kept at about 0·005 cm. for a period of 10 minutes, which was sufficient to obtain a stationary effect on the photographic plate produced by the evacuation. Two pieces of photographic plates were cut from one plate, and these were put into the plate holder, and a series of exposure were made by the H & D wheel, one at ordinary pressure and the other at the reduced pressure, and these were then developed together.

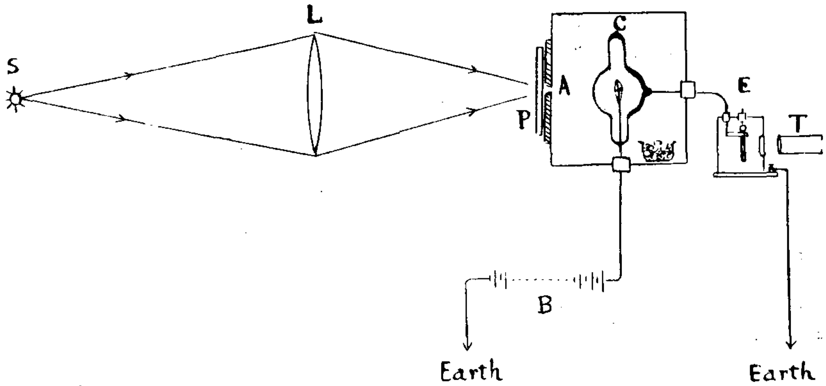
The developer recommended by the makers of the plate was first used, but on account of the weather the fluctuation of chemical fog was very troublesome and consequently the following developer was constantly used,

A	Metol	20 grs		B	Sodium Carbonate	2 ozs
	Hydroquinone	70 grs			Potash Bromide	20 grs
	Sodium sulphite	3 ozs			Water up to	20 ozs
	Water up to	20 ozs				

equal parts of A and B being mixed for use. The duration of the developement was fixed at 3 minutes, for which the characteristic curve nearly reached to a maximum inclination or γ_∞.

The density of the balckening was measured photoelectrically by means of a Kunz's photoelectric cell, the arrangement of the apparatus for the photometry being shown in Fig. 4.

Fig. 4.



S is the light source which is the same as used in the previous experiment, L is a condensing lens and P the photographic negative to be measured. A is a small circular aperture 1 mm. in diameter, and C represents the photoelectric cell placed in a box containing calcium chloride. B is a battery of 60 volts, the positive terminal of which was connected to the leaf of an electroscope E, the walls of which were earthed. The leaf of the electroscope was negatively charged, and the rate of falling of the leaf was measured with a low power microscope. The intensities of lights transmitted through the various parts of the plate were compared by the reciprocal of the time with which the leaf travelled between two fixed points in the micrometer of the microscope, correction for the natural leakage and for the fog of the negative being of course necessary.

Now, let t' be the time required by the leaf to travel between the two fixed points when the aperture was shut, and t the corresponding time when the photoelectric cell was illuminated by the ray passing through a part of the plate to be measured, and t_0, the value of t for the most transparent part of the plate i. e. for the fog only. Then we have the following expression for the intensity of incident light I_c and that of transmitted light I,

$$I_o = k\,(1/t_o - 1/t')$$
$$I = k\,(1/t - 1/t')$$

k being the proportional factor. From these we have the density D as follows.

$$D = \log\,(I_o/I) = \log \frac{1/t_o - 1/t'}{1/t - 1/t'}$$

Experimental results.

The influence of evacuation on the blackening of the plate produced by exposures made under reduced pressure was thus measured for plates of various brands, and the densities of the evacuated plates corresponding to the series of exposures of 2^n were compared with those of untreated ones. The results thus obtained are given in Table 1.

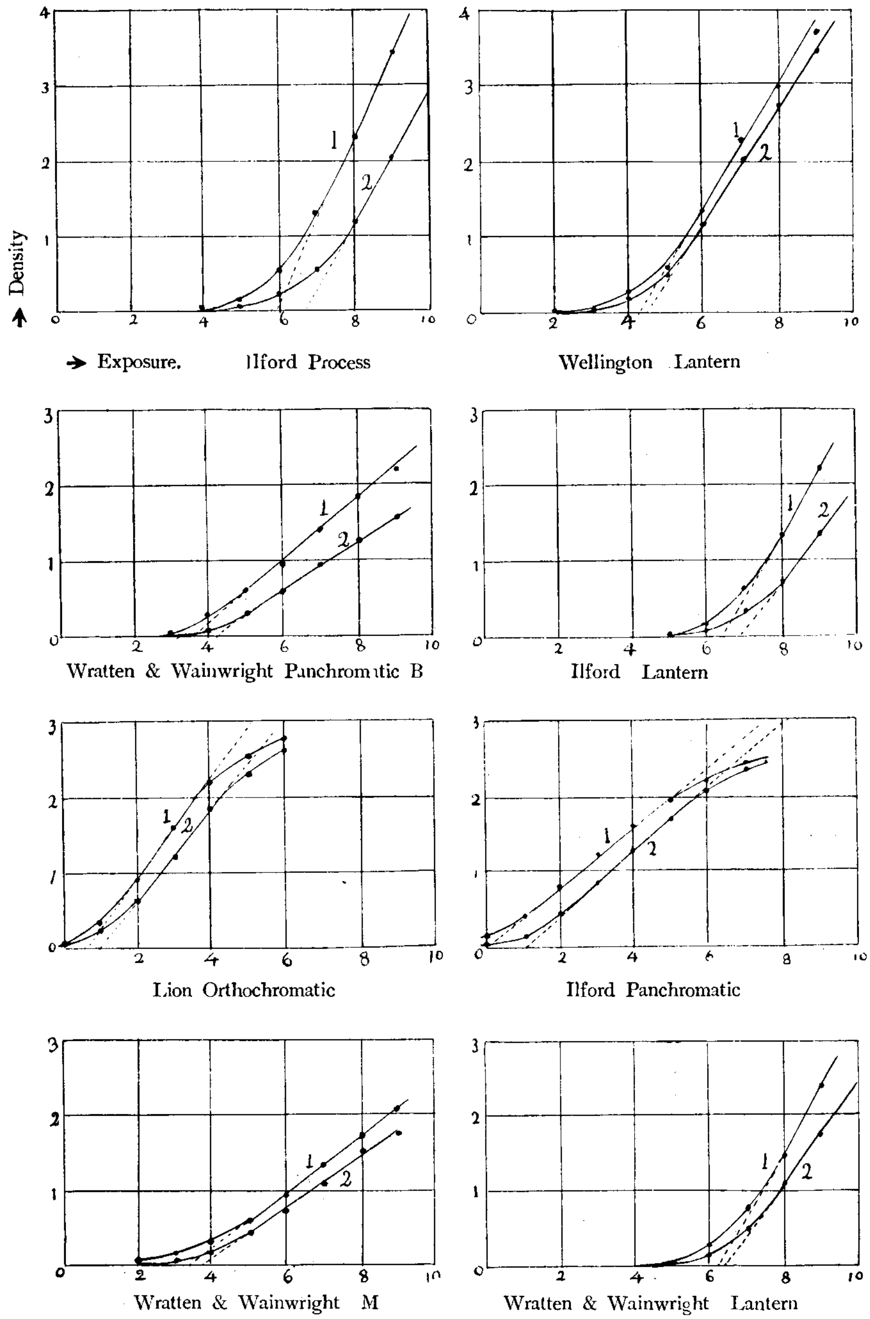
Table 1.

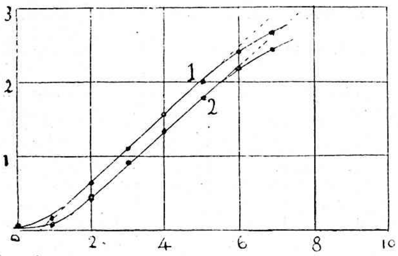
Name of Plate	Time of Exposure		Density							
			$n=0$	$n=1$	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
Ilford Process	8min.	Untrest.			·023	·075	·248	·624	1·269	2·041
		treat.			·019	·137	·591	1·322	2·355	3 449
Wratten & Wainwright Panchr. B	8min.	untrest.		·013	·086	·245	·570	·947	1·322	1·623
		treat.		·093	·236	·610	·974	1·495	1·888	2·209
Lion Ortho	4min.	untrest.	·224	·625	1·244	1·831	2·297	2 599		
		treat.	·371	·932	1·610	2·181	2·481	2·732		
Wellington Lantern	8min.	untrest.	·013	·057	·207	·579	1·212	2·037	2·773	3·427
		treat.	·013	·051	·191	·512	1·337	2·292	2·956	3·710
Wratten & Wainwright M	8min.	untrest.	·000	·035	·195	·412	·763	1·107	1·511	1·761
		treat.	·057	·199	·385	·662	·967	1·369	1·7[illegible]2	2·068
Ilford Special Rap.	2min.	untrest.		·111	·481	·898	1·364	1·781	2·140	2·4[illegible]8
		treat.		·155	·637	1·117	1·597	1·989	2·330	2·590
Ilford Lantern	8min.	untrest.				·000	·053	·312	·752	1·354
		treat.				·021	·152	·602	1·380	2·230
Ilford Panchr.	2min.	untrest.	·045	·124	·410	·892	1·365	1·784	2·102	2·380
		treat.	·124	·464	·834	1·207	1·574	1·914	2·163	2·438
Wratten & Wainwright Lantern	8min.	untrest.				·061	·185	·504	1·090	1·773
		treat.				·076	·281	·802	1·436	2·344
Stanley	2min.	untrest.	·037	·075	·223	·462	·732	1·033	1·356	1·642
		treat.	·037	·146	·320	·558	·853	1·164	1·453	1·738
Wellington Isospeedy	2min.	untrest.	·027	·091	·363	·758	1·164	1·553	1·899	2·168
		treat.	·027	·151	·393	·787	1·223	1·625	2·002	2·318

From these the characteristic curves are drawn as given in Fig. 5, A and a few examples of the photographs are given in Fig. 5, B.

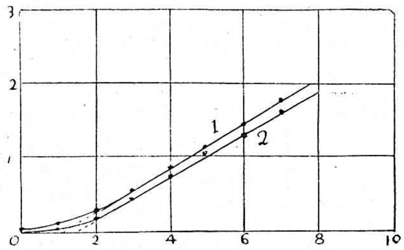
Fig. 5, A.

1 Treated plate.
2 Untreated plate.



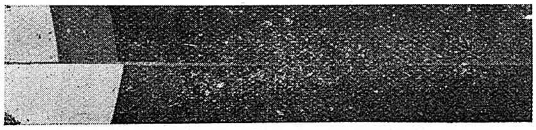


Ilford Special Rapid

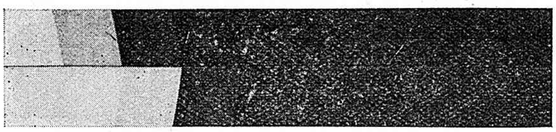


Stanley

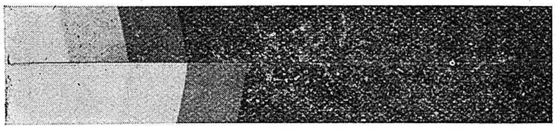
Fig. 5, B.



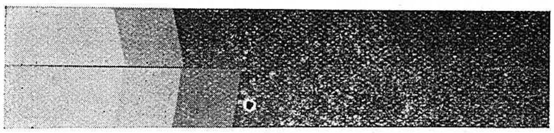
Untreated } Treated } Wratten & Wainwright Process



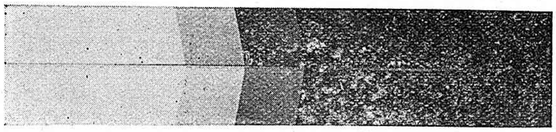
Untreated } Treated } Ilford Process



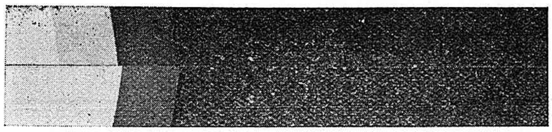
Untreated } Treated } Wratten & Wainwright Panchro. B



Untreated } Treated } Wratten & Wainwright M



Untreated } Treated } Ilford Panchro.



Untreated } Treated } Wratten & Wainwright Lantern

It will be observed from the figures that the sensitivity of many of the plates is increased or their inertia decreased by previous evacuation, while the slope of the curve or the contrast increases for many plates, Ilford Panchromatic plate being the exception to this rule. It seems to me that, although no definite relation could be found between the structure of the emulsion and the evacuation effect, the evacuation has generally a stronger sensitizing action upon emulsions that have smaller and more homogeneous grains than upon the emulsion of high speed plates.

The variation of the pressure.

Next, the influence of the variation of the amount of the reduced pressure upon the form of the characteristic curve of a photographic plate was studied. In this experiment the pressure was varied from 40 cm. to 0.002 cm. and the changes of the inertia and the contrast were observed. The results are given in Table 2. The curves in Fig. 6 were drawn from these deta.

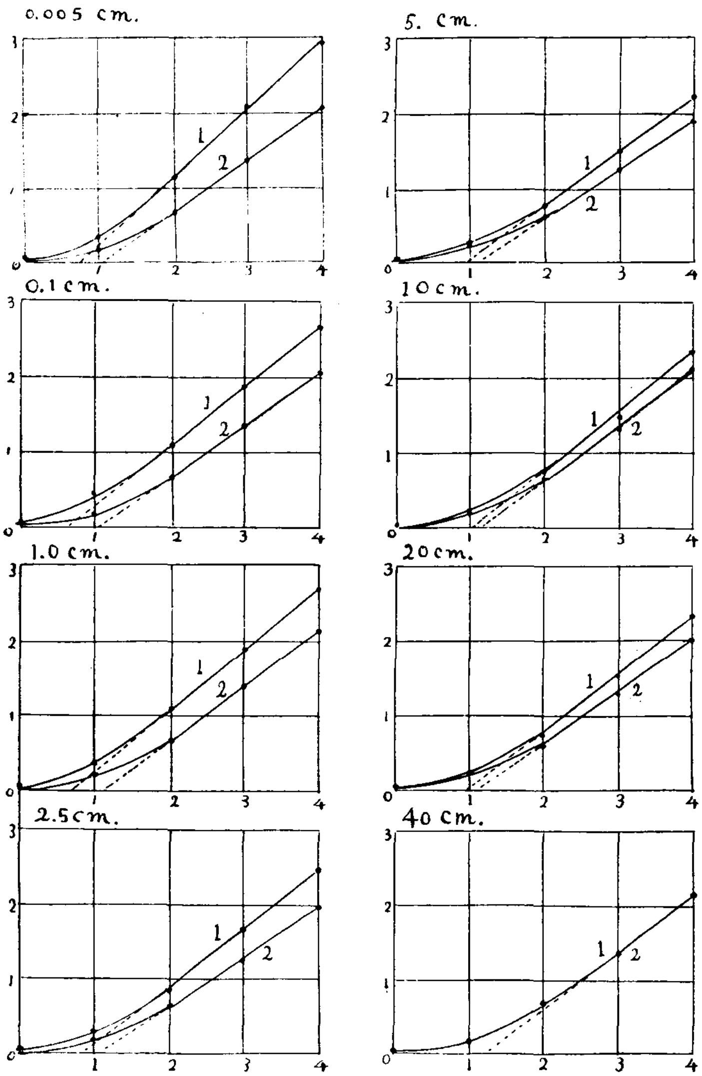
Table 2.

Degree of Vacuum	Density (treated)				Density (untreated)			
	$n=4$	$n=5$	$n=6$	$n=7$	$n=4$	$n=5$	$n=6$	$n=7$
40 cm.	·243	·726	1·391	2·170	·303	·736	1·401	2·188
20 cm.	·243	·736	1·508	2·344	·274	·579	1·250	2·049
10 cm.	·243	·737	1·494	2·332	·243	·645	1·301	2·117
5 cm.	·274	·747	1·439	2·210	·244	·633	1·201	1·975
2·5 cm.	·348	·884	1·628	2·405	·303	·606	1·263	2·010
1·0 cm.	·330	1·062	1·892	2·665	·303	·658	1·352	2·140
0·1 cm.	·401	1·072	1·833	2·663	·176	·647	1·270	2·041
0·002 cm.	·303	1·104	2·004	2·883	·177	·640	1·310	2·033

(Ilford Process plate)

Fig. 6.

1 Treated plate.
2 Untreated plate.



It is concluded from these curves that the inertia i decreases while the contrast increases more and more as the pressure approaches to zero. It will perhaps be said that i and γ vary nearly exponentially as the pressure decreases.

It must be noticed that in the present experiments the photographic plate was exposed while under reduced pressure but when the plate was exposed after the pressure was restored to one atmosphere, the changes of i and γ were smaller than the corresponding former values.

Prolonged exposure to a light having a very small photographic effect.

As the peculiar effect of red light mentioned in the previous paragraph is specially interesting in the investigation of fog, the evacuation effect upon ordinary photographic plates exposed to red light was studied.

The light source in the above experiments was replaced by a 250 watt incandescent lamp with condensed filament, and this was placed in a box having a circular aperture 2 cm. in diameter and the light was filtered through Wratten's monochromat β. The experiment was performed in a similar way to the preceding and the results of the measurements are given in Table 3. From these the curves in Fig. 7 were drawn.

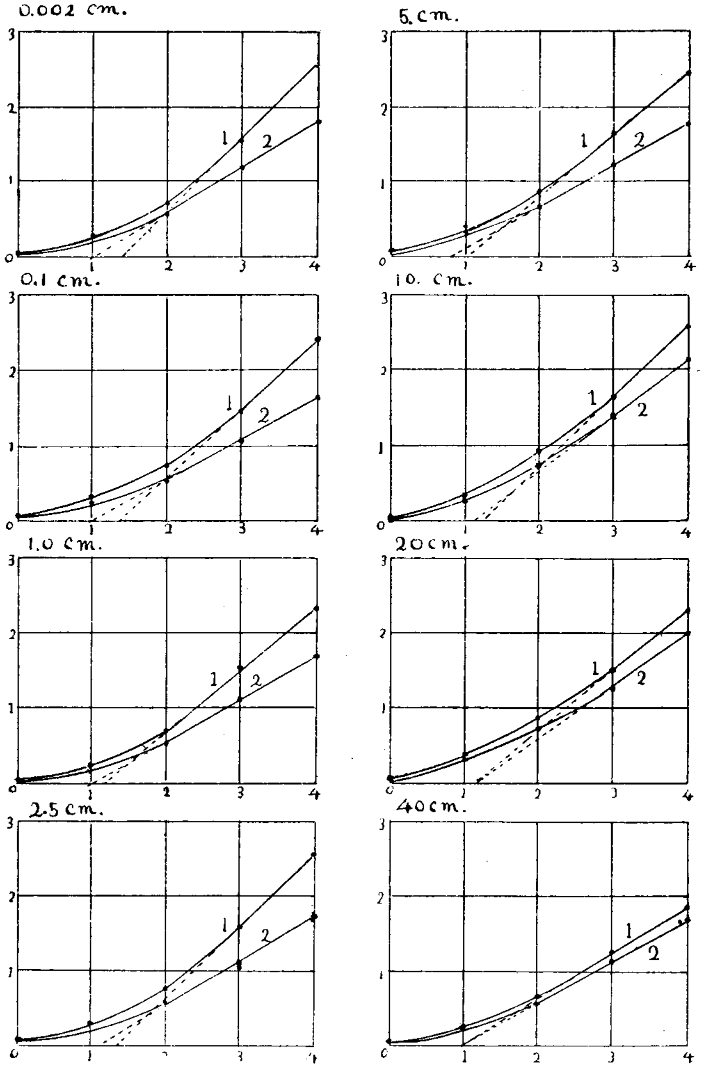
Table 3.

Degree of Vacuum	Density (treated)				Density (untreated)			
	$n=4$	$n=5$	$n=6$	$n=7$	$n=4$	$n=5$	$n=6$	$n=7$
40 cm	·387	·666	1·293	1·882	·332	·653	1·176	1·702
20 cm	·412	·826	1·501	2·214	·387	·808	1·276	1·955
10 cm	·412	·914	1·667	2·596	·362	·731	1·387	2·152
5 cm	·387	·863	1·629	2·435	·332	·638	1·219	1·777
2·5 cm	·303	·771	1 588	2·622	·236	·607	1·138	1·705
1·0 cm	·236	·706	1·500	2·377	·196	·520	1·146	1·761
0·1 cm	·301	·731	1·489	2·413	·236	·539	1·121	1·693
0.002 cm	·303	·787	1·571	2·553	·303	·579	1·182	1·824

(Ilford Process plate.)

Fig. 7

1 Treated plate.
2 Untreated plate.

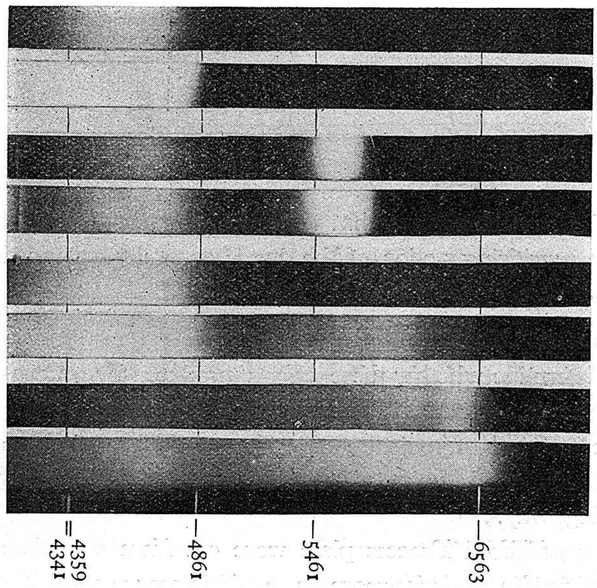


The difference of the above results from these obtained with white or violet light as the source of the light is that in the present case the inertia is increased i. e. the sensitivity is decreased by evacuation. The reverse was true in the former case. Another difference is that in the present case the contrast, i. e. γ, remarkably increases as compared with the former case. Consequently two straight lines representing the normal portions of two characteristic curves of treated and untreated plates intersect at a point on their extension. If the exposure is made after the pressure is restored to the atmospheric this point seems to shift upward. Hence the density of a treated plate is less than that of an untreated one when the exposure is short. When ordinary plates such as Ilford Special Rapid and Stanley were used, this decrease of sensitivity and increase of contrast were more remarkable. This fact is in harmony with the statement given in the previous paragraph, that the fog produced on the evacuated plate during developement under a ruby light is less than that on an untreated plate.

Wave length of the source.

Next, the relation between the sensitizing action of reduced pressure and the wave length of the exposed light was studied. For this purpose a continuous spectrum produced by a grating spectrograph was photographed simultaneously on a plate in a partial vacuum and on another plate at normal pressure. For the determination of the wave length, the spectra of hydrogen and mercury emitted from a vacuum tube were photographed on the same plate. From these plates the densities were determined. The results are shown by the curves in Fig. 8, B and by reproductions of some of the photographs in Fig. 8, A.

Fig. 8, A



Untreated } Ilford Process.
Treated

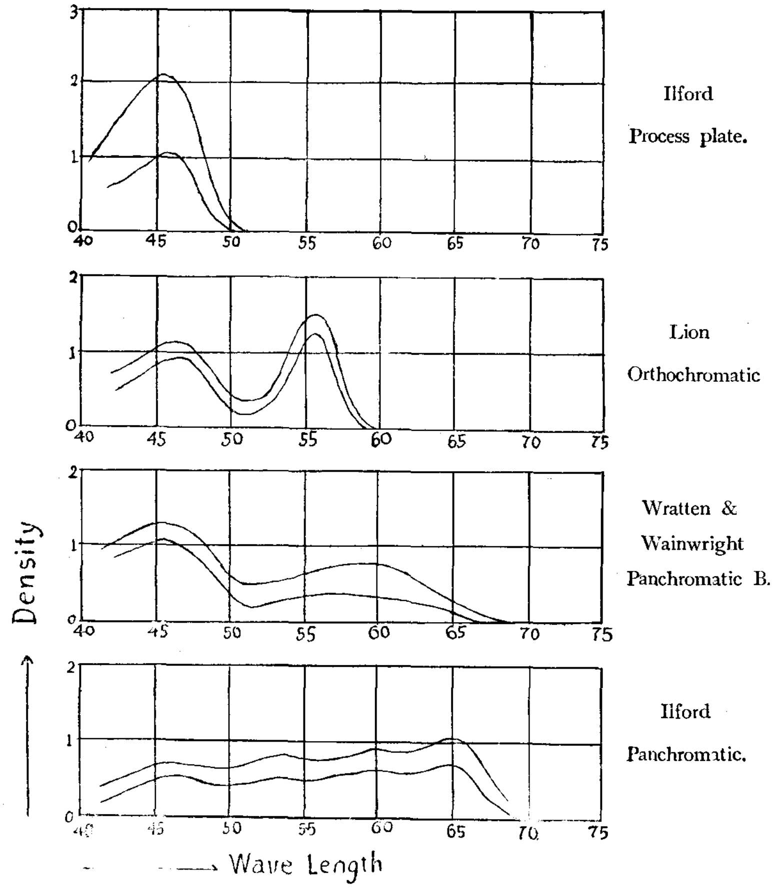
Untreated } Lion Ortho.
Treated

Untreated } Wratten and Wainwright Panchro. B.
Treated

Untreated } Ilford Panchro.
Treated

Fig. 8, B

1 Treated plate.
2 Untreated plate.



It will be observed from the figures that the sensitizing action is not so marked, but that the sensitizing action of the dye is generally enhanced by the evacuation.

Cause of the Evacuation effect.

It is important to determine whether these effects produced by evacuation upon a photographic plate are to be attributed simply to the reduced pressure itself or to the removal of moisture or other occulted gases from the photographic plate. From this point of view the effect of drying was examined in the following way.

A number of pieces of Ilford Process plate were cut from one plate and half of them were dried in a dark room in a desiccator containing phosphorous pentoxide. A plate was taken out from the desiccator at the times given in Table 4, and a series of exposures by the H & D sector-wheel was made simultaneously on this dried and on another undried one. The characteristic curves were then drawn as shown in Fig. 9 from the data given in Table 4.

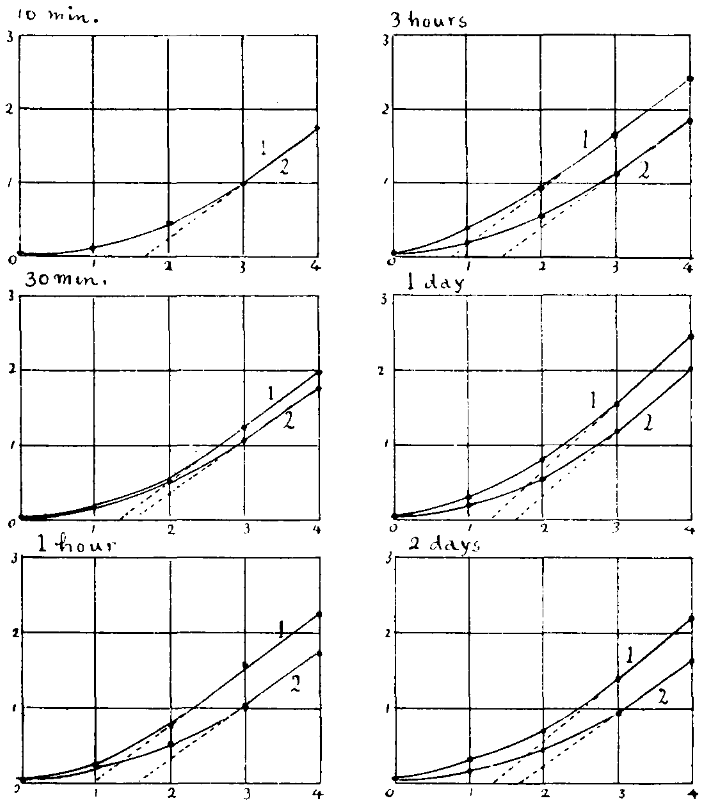
Table 4.

Time of Drying	Density (treated)				Density (untreated)			
	$n=4$	$n=5$	$n=6$	$n=7$	$n=4$	$n=5$	$n=6$	$n=7$
10 min	·140	·462	1·004	1·737	·177	·481	·974	1·747
30 min	·212	·580	1·215	1·992	·244	·532	1·062	1·805
1 hour	·303	·805	1·683	2·265	·212	·562	1·004	1·785
3 hours	·401	·928	1·667	2·433	·212	·549	1·130	1·838
1 day	·354	·840	1·582	2·483	·244	·580	1·207	2·068
2 days	·330	·695	1·362	2·114	·176	·442	·922	1·661

(Ilford Process plates.)

Fig. 9

1 Dried plate.
2 Untreated plate.



On the other hand, the effect of moisture upon the plate was also examined in a similar way with a plate, one half of which was purposely wetted with water. A few pieces cut from one plate were put in water for five seconds, and then dried in the desicator for various durations of time. Now, one of these was taken out at the times given in Table 5 and this was exposed with an untreated plate in the same way as above. From these experiment the results given in Table 5 and in Fig. 10 were obtained.

Fig. 10

1 Untreated plate.
2 Wetted plate.

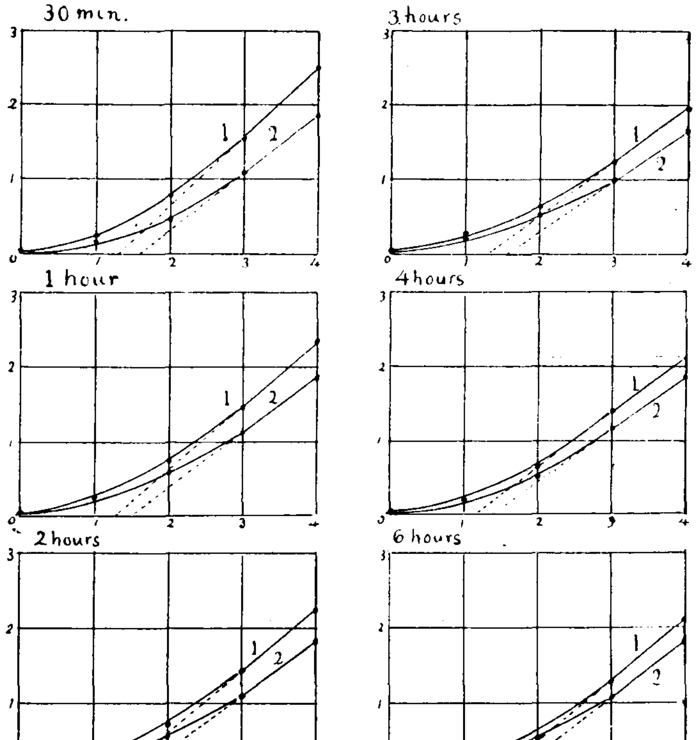


Table 5.

Time of Drying	Density (treated)				Density (untreated)			
	$n=4$	$n=5$	$n=6$	$n=7$	$n=4$	$n=5$	$n=6$	$n=7$
30 min	·193	·480	1·104	1·892	·277	·819	1·522	2·453
1 hour	·250	·642	1·146	1·872	·277	·769	1·407	2·312
2 hours	·250	·582	1·102	1·809	·277	·753	1·408	2·217
3 hours	·223	·542	·999	1·772	·301	·619	1·240	1·992
4 hours	·223	·596	1·183	1·937	·250	·686	1·398	2·104
6 hours	·223	·525	·999	1·762	·223	·593	1·204	2·043

(Ilford Process plate.)

It will be seen that the dry plate has always less intertia than the moist plate and that the contrast is slightly greater in the dry plate.

Comparing these with the effect of the evacuation upon the photographic plates, many analogous points may be found. Therefore the greater part of the effect produced by the evacuation may be attributed to the drying of the emulsion.

The influence of moisture upon the photographic effect was studied by J. Sterry.[1] He found that a moist plate has less sensitivity, but higher contrast than a dry plate. But in the present experiment the reduction of the pressure to which the emulsion is subjected increases the sensitivity but also increases the contrast of the density, with a few exceptions. Moreover some phenomena such as the less fog upon the evacuated plate exposed in the developer seems to require another explanation besides the drying of emulsion. But the effect of evacuation itself, even if it really exists, will be less than the effect of drying. The removal of other occulted gases will also play some part in these effects.

The reduction of pressure of an already exposed photographic plate also changed its inertia and contrast, but the amounts were generally small.

In conclusion I wish to express my gratitude to Prof. M. Kimura who kindly directed my experiments.

Summary.

By reducing or increasing the pressure on the surface of photographic emulsion it may be possible to vary the sensitiveness and the contrast of density. The author has examined the variations of inertia and contrast by evacuation.

In many plates the inertia was decreased, i.e. the sensitivity was

1 Phot. J. **54**, 50, (1904).

increased and also the contrast was increased by the evacuation of the photographic emulsion before the exposure. Similar and more remarkable results were obtained when the plate was exposed in a partial vacuum. These effects were generally greater in plates of low speed than in those of high speed.

In the case of prolonged exposure to light that has a very small photographic action on the plate in the partial vacuum, the sensitivity inversely decreased while the contrast increased more markedly than in the previous case, and the two characteristic curves, treated and untreated, intersect at a point. Therefore the evacuated plate had greater density than the untreated when the exposure to the red light was shorter. Hence there was less fog on the evacuated plate than on the untreated plate during developement.

The greater part of these effects may be attributed to the drying of the emulsion, while the removal of other occulted gases probably plays some part in these effects.