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Hypersensitization and Reciprocity Law Failure

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HYPERSENSITIZATION AND RECIPROCITY LAW FAILURE

by

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to

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ABSTRACT

Two sets of Super XX cut film strips were hypersensitized under varying conditions of hypersensitizing agent used, concentration of hypersensitizing solution and time of hypersensitizing. The strips were rapidly dried and exposed. One set was exposed with a high film plane illuminance for 5.0 seconds, and the second set was exposed with a low film plane illuminance for 10^4 seconds. The difference in exposure necessary to give a density of 1.50 for the strips of each set was used as a measure of the reciprocity law failure. From the H and D curves of each test a measure of the fog level and gamma of the material was also measured.

A statistical analysis of the data showed that the low intensity failure of the receprocity law was reduced after hypersensitization and that this reduction was accomplished with no change in gamma and with a slight increase in the fog level under the optimum conditions.

BACKGROUND INFORMATION

A serious problem to the astronomical photographer has been the low intensity failure of the reciprocity law. Exposures necessary under these conditions may be three or four times what would be required with a source of greater intensity.

The problem can be eliminated by making exposures at low temperatures (-40° to -75° C.), however this is a relatively troublesome procedure.

Hypersensitization by water or alkaline solutions has been used for many years as a method to increase the speed of a photographic material. It has been found that most of these hypersensitizing agents will increase speed to a greater degree for longer rather than shorter exposures.[1] Bowen and Wyse state that for Agfa Superpan Press, hypersensitization increased the speed 1.3 times for a twenty second exposure and 3.0 times for a twelve hour exposure.[2]

The purpose of this investigation was to make a statistical analysis of the decrease in reciprocity law failure after hypersensitizing and to discover which levels of the significant factors gave the greatest decrease in the reciprocity law failure, and to find if these levels had the detrimental effect of increasing fog or gamma of the material.

The hypersensitizing agent, the concentration of that agent, and the time of hypersensitizing were the three factors tested. The results apply only to the conditions of this investigation since the effect of hypersensitizing will be significantly changed with different conditions.[3]

OBJECTIVES

The purpose of this investigation into the effect of hypersensitization upon reciprocity law failure is to find the answers to the following questions :

1. Is hypersensitization by the use of ammonium hydroxide, borax, or a mixture of 50% ammonium hydroxide and 50% borax capable of significantly reducing low intensity reciprocity law failure ? If so, which of these agents achieves the greatest reduction ?
2. Will the concentration of the hypersensitizing agent significantly affect the decrease in reciprocity law failure ? If so, what concentration gives the greatest decrease ?
3. Will the length of time of hypersensitizing significantly change the decrease of reciprocity law failure ? If so, what time gives the greatest decrease ?
4. Do any of the above mentioned factors significantly increase fog or the gamma of the material ?

EXPERIMENTAL PROCEDURE

<u>Photographic material</u> : Kodak Super XX cut film.

<u>Developer</u> : Kodak DK-50 developer, undiluted, for five minutes at 18° C. using standard A.S.A. tray agitation.

<u>Borax hypersensitizing solution</u> : Desired concentrations mixed on a weight-volume relationship.

<u>Ammonium Hydroxide hypersensitizing solution</u> : Desired concentration mixed on a volume relationship.

<u>50% borax-50% ammonium hydroxide mixture hypersensitizing solution</u> : Desired concentration mixed on a volume relationship.

<u>Exposure</u> : Film was placed in a contact printing frame using a Kodak # 2 step tablet to attenuate the exposure. The frame was placed a known distance from a ten watt source. (see appendix 1 and 2)

<u>Hypersensitizing</u> : The film was treated for the desired time in the hypersensitizing agent at 18° C. A.S.A. standard tray agitation was used during the treatment.

<u>Intensity measurements of source</u> : The measurements were made on a Lummer Brodhun visual photometer. (R.I.T. Mechanical department)

<u>Film drying</u> : After hypersensitizing the film was dried for eight minutes in a drying tunnel. (see appendix 3)

<u>Experimental Design</u> :

concentration

	time	0%	1%	2%	4%	6%
ammonium hydroxide	0 min					
	2					
	4					
	8					
	16"					
borax	0 min					
	2					
	4					
	8					
	16"					
mixture	0 min					
	2					
	4					
	8					
	16"					

Experimental method : Seventy-five strips were individually treated. They were each first hypersensitized according to the experimental design then rapidly dried in the drying tunnel. Each strip was then exposed for 10^4 seconds and processed. Each strip was measured on a densitometer, an H and D curve was drawn, and the exposure necessary to give a density of 1.50 was calculated. A second set of seventy-five strips was also individually treated in the same way as above except that they were exposed for 5.0 seconds. The response variable was then calculated for each treatment by subtracting the exposure necessary to give a density of 1.50 for the short exposure strips from the exposure necessary to give a density of 1.50 for the long exposure strips for each corresponding treatment. Further data was gathered by measuring the fog level for each treatment and calculating the gamma of the material for each treatment. Three statistical analyses of variance tests were then made. The first to find which factors significantly reduced the reciprocity law failure, the second to find which factors significantly increased fog, and a third to find which factors significantly increased the gamma. After the significant factors were found for each of the three response variables, orthogonal comparison tests were made to discover which levels of these factors caused the significant difference. If some pattern appeared in these tests a third statistical analysis was run to find if the relationship between the levels was linear, quadratic or cubic.

EXPERIMENTAL RESULTS

The following statements represent results of statistical analysis of the data. The single asterisk (*) represents statistical significance at a risk of .05 (5%) ; the double asterisk (**), at a risk of .01 (1%); and a triple asterisk (***), at a risk of .001 (.1%).

The time of hypersensitization (***) and the agent used for the hypersensitization (*) reduced the reciprocity law failure of the material. The concentration of the solution and all interactions between factors did not have this significant effect. (see Appendix 4) . No difference was found between the use of ammonium hydroxide or borax solutions, however both of these agents reduced the failure more than the mixture of borax and ammonium hydroxide (**). No difference was found between any of the different times of hypersensitization tested except when compared with zero time (***), which were tests that received no hypersensitizing treatment.

The main factors, hypersensitizing agent used (**), the time of hypersensitizing (***) and the concentration of the hypersensitizing agent(***), increased the fog level of the film. (see appendix 5) The ammonium hydroxide increased the fog level to a greater degree than the borax solution (**) or the ammonium hydroxide-borax mixture (***). There was no difference in the fog level between using the mixture or the borax solution. The samples having had no hypersensitizing treatment had a lower fog level than those having been hypersensitized of any of the other times tested (***). However, the eight minute treatment increased the fog level more than the two minute treatment (***). Although this increase in fog with increase in time of treatment existed, no linear, quadratic, or cubic relationship was found between them. (see appendix 6). No difference was found between the samples treated with 1%, 2% or 4% solutions and the samples treated with water (0%). The 6% concentration solution increased the fog more (***) than any of the other concentrations. An interaction between the hypersensitizing agent used and the time of hypersensitizing (***), and an interaction between the hypersensitizing agent used and the concentration of the solution (***) existed which increased the fog level of the material. (see appendix 5)

The time of hypersensitizing (*) and the concentration of the solution (**) increased the gamma of the material tested. (see appendix 7) The sixteen minute time of hypersensitizing increased the gamma over the tests that received no treatment(*). The other times of hypersensitizing did not increase the gamma. The 4% and 6% concentrations both increased the gamma over tests hypersensitized with a less concentrated solution (*). There was no difference in gamma with tests hypersensitized in 0% (water), 1% or 2% concentrated solutions. There was no linear, quadratic, or cubic relationship found between the concentration of the hypersensitizing solution and the gamma of the photographic material. (see appendix 8)

SUMMARY

The following statements apply only to the specific conditions under which this investigation was performed.

Hypersensitization by ammonium hydroxide or borax solutions reduces the reciprocity law failure to the greatest degree. The ammonium hydroxide,however, increased the fog level most.

The length of time for which the film is hypersensitized will not affect the decrease in reciprocity law failure just so it does receive some treatment. The shorter the time of hypersensitizing possible is best in order to keep the log level to a minimum. If the film is hypersensitized for more than eight minutes the gamma will increase.

The concentration of the hypersensitizing solution does not affect the decrease in reciprocity law failure. However, if the concentration exceeds 4%, the fog level will increase; or if the concentration exceeds 2%, the gamma of the material will increase.

The optimum condition is a hypersensitizing time of two minutes or less in a 1% or 2% solution of borax. This will give the smallest increase in fog, no change in gamma and will reduce the reciprocity law failure of the photographic material.

DISCUSSION

In this discussion the term "speed" refers to the exposure necessary to give a density of 1.50, and the statements are applicable only to the optimum conditions as found in this investigation.

Hypersensitization increased the speed of the material 1.69 times for exposures of 5.0 seconds and 3.20 times for exposures of 10^4 seconds thus decreasing the low intensity reciprocity law failure. Since the inherent failure of the material requires an increase of only 1.90 times when exposed at very low illuminance levels, hypersensitization will increase the speed sufficiently so that the film may be given 1.64 times less exposure at a low illuminance level than would be required under normal short exposure, high illuminance, sensitometric conditions. The increase in fog would usually not be of great concern since the increase was only of the order of 1.29 times.

According to published reciprocity law failure curves[4], if an exposure is made at -40° C. to a low intensity source, the photographic material will have the same speed as it would have if exposed to a high intensity source at room temperature. However, for low illuminance level photographic work the hypersensitizing method would be preferable to the low temperature method because it will give the film a greater speed than it would have under normal sensitometric conditions, and because it is less troublesome to perform.

APPENDIX

1. Film plane during exposure

2. Light source used for exposures

3. Tunnel to rapidly dry film after hypersensitizing

APPENDIX (CONT.)

4. Analysis of variance table for reciprocity law failure.

source	sum of squares	degrees of freedom	mean square	$F_{.05}$	F
agent	0.32	2	0.16	3.15	3.55 *
concentration	0.30	4	0.075	2.53	1.66
time	38.99	4	9.75	2.53	216.6***
AT	0.38	8	0.047	2.27	1.00
AC	0.48	8	0.060	2.27	1.27
TC	0.49	16	0.031	2.01	0.660
residual (ATC)	1.50	32	0.047		
total	42.08	74			

5. Analysis of variance table for fog.

source	sum of squares	deg. free.	mean square	$F_{.05}$	F
agent	0.003	2	0.0015	3.32	8.02**
concentration	0.005	4	0.0013	2.69	6.95***
time	0.015	4	0.0375	2.69	200.5***
AT	0.002	8	0.0013	2.27	5.90***
AC	0.002	8	0.0013	2.27	5.90***
TC	0.002	16	0.00013	2.01	0.590
residual(ATC)	0.007	32	0.00022		
total	0.036	74			

APPENDIX (CONT.)

6. Analysis of variance table for linear, quadratic or cubic effect of time of hypersensitizing upon fog.

between levels of time	sum of squares	degrees of freedom	mean squares	$F_{.05}$	F
linear effect	0.00601	1	0.00601	161	4.63
quadratic effect	0.00486	1	0.00486	161	3.74
cubic effect	0.00281	1	0.00281	161	2.16
remainder effect	0.0013	1	0.0013	161	
total effect of time	0.015	4			

7. Analysis of variance table for gamma.

source	sum of squares	degrees of freedom	mean square	$F_{.05}$	F
agent	0.03	2	0.015	3.15	1.68
time	0.11	4	0.028	2.53	3.14*
concentration	0.15	4	0.038	2.53	4.27**
AT	0.11	8	0.014	2.27	0.422
AC	0.14	8	0.018	2.27	0.546
TC	0.32	16	0.020	2.01	0.608
residual (ATC)	1.40	32	0.033		
total	1.90	74			

APPENDIX (CONT.)

8. Analysis of variance table for linear, quadratic or cubic effect of concentration upon gamma.

between levels of concentration	sum of squares	degrees of freedom	mean square	$F_{.05}$	F
linear effect	0.0280	1	0.0280	161	0.474
quadratic effect	0.0464	1	0.0464	161	0.786
cubic effect	0.0161	1	0.0161	161	0.274
remainder effect	0.059	1	0.059	161	
total effect of concentration	0.150	4			

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SUPPLEMENTARY REPORT
HYPERSENSITIZATION AND RECIPROCITY LAW FAILURE

Charles N. West

Drying Film After Hypersensitizing

After the film has been hypersensitized , it is important that it be dried evenly and rapidly. If this is not done, the speed of the film will be increased unevenly resulting in uneveness of density. If a drying tunnel is used such as was done in this work, the film must be hung with its edge toward the fan. If it it is hung with the side toward the fan, eddy currents of air will cause uneven drying. A device such as a women's hair drier if used, would probably be preferable to assure even drying. Also after hypersensitizing a short bath in alcohol would probably be extremely helpful to assure even drying.

Statistical Analysis

Care and forsight when making statistical analyses is very helpful. During this investigation, a test to find a linear, quadratic, or cubic relationship between levels was made on every quantitative significant factor. This was not intelligent for some factors that had four levels that gave very close results and one level which was much different. It was obvious that no relationship existed between the levels so a test to find one was not sensible.

Hypersensitizing Agents

Borax and ammonium hydroxide are rather troublesome agents to use. Borax has a very low solubility and ammonium hydroxide has an extremely pungent odor although these are the two commonly used hypersensitizing agents. It would be very worthwhile to find if some other alkali such as sodium hydroxide, an organic amine such as aniline, or a alkaline salt such as sodium acetate would work as well and be easier to use. Water should also be tested as a possible hypersensitizing agent. It was used in this project as the zero level of concentration but as such could not be compared with the other agents tested.

The Factor, Time of Hypersensitizing

The shortest time of hypersensitizing tested in this project was two minutes, and this was found to be the optimum length of time to use. There may, however, be an even shorter time that will give as great a decrease in reciprocity law failure and give less or no increase in fog. Also the shorter the time that can be used the more convenient the method will be.

The Photographic Material

This investigation was made using ordinary cut film. In practice astronomical plates would be used for low intensity work. These plates inherently have a flatter reciprocity failure curve than the film used. It would be worthwhile to make an investigation of this kind using astronomical plates to see if the treatment would work as well or better. The results of such tests would be of practical importance to the astronomical photographer, for instance, for whom the increased sensitivity and the dimensional stability of glass are important.

Resolving Power, Acutance, and Granularity

Increase in fog and gamma were the only two possible detrimental effects of hypersensitizing that were tested.

For this method to be of real value, it would be necessary to know if resolving power, acutance or granularity were affected by hypersensitization. It would be most appropriate to test for these in future work. I know of no published results of work of this kind.