1979

A Study of the Mechanism of the Sabattier Effect

Steven Oshry

A STUDY OF THE MECHANISM OF THE SABATTIER EFFECT

Undergraduate Research Thesis

By: Steven B. Oshry
Submitted to: Department of Photographic Science and Instrumentation
Rochester Institute of Technology
Advisor: Dr. B.H. Carroll
Date: 5/11/79

G-925596

ABSTRACT

Conditions for producing the Sabattier effect in Eastman fine grain release positive 5302 film were established. Modifications of the second developer to develop more internal latent image by the addition of potassium iodide or to increase solution - physical development by the addition of sodium thiocyanate and.sodium sulfite were performed. These modifications made no significant change in the Sabattier effect. When chemical fog (from sodium borohydride) was substituted for the exposure during development , no reversal corresponding to the Sabattier effect was obtained.

INTRODUCTION

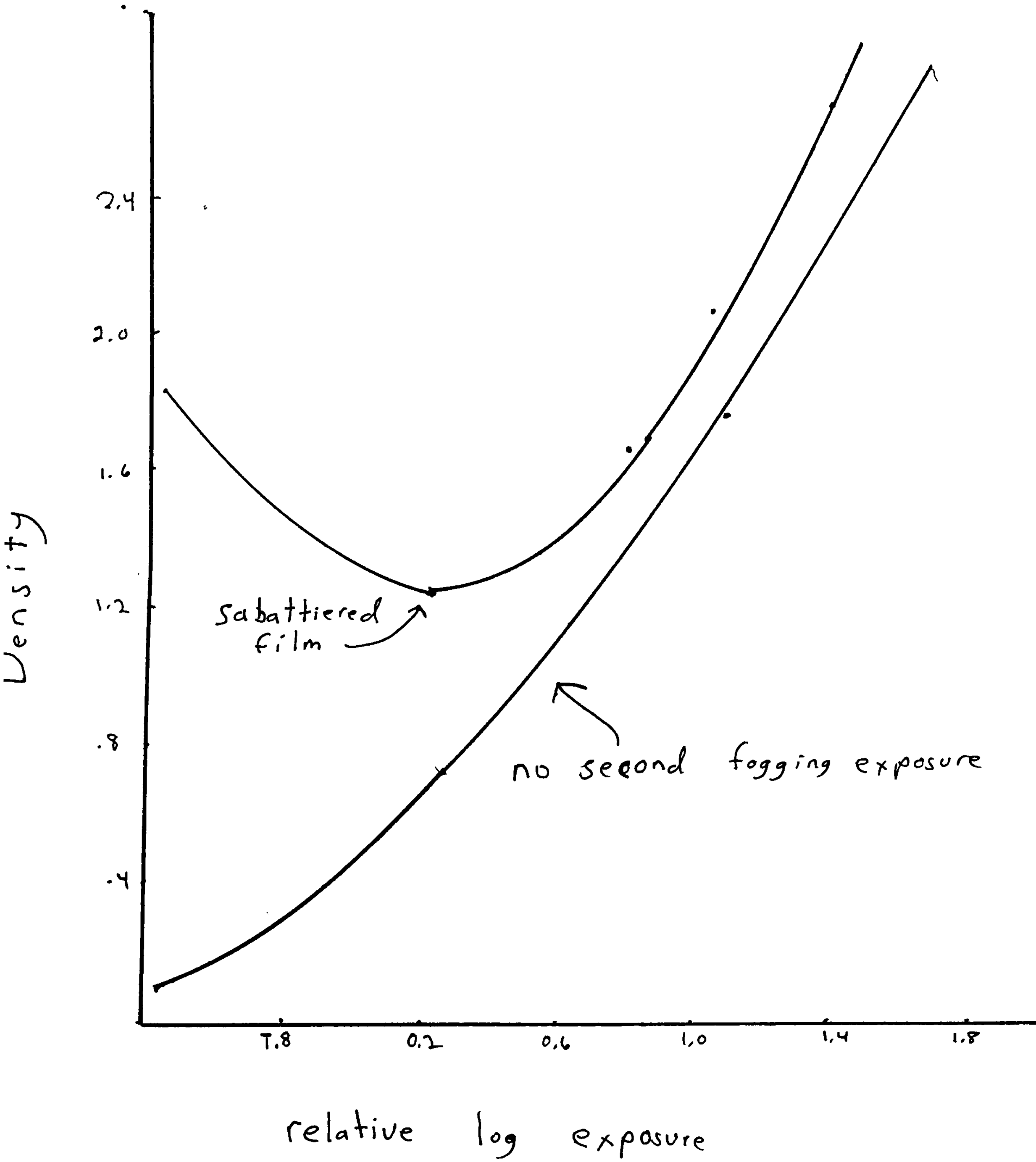
The Sabattier effect is an exposure effect which exhibits some interesting characteristics. This effect is often incorrectly referred to as solarization by professional photographers. The Sabattier effect is used in pictorial photography for its white line border effect and the reversal corresponding to low first exposures. This effect is obtained in a photographic emulsion by uniformly re-exposing the emulsion during development.

The resulting image is reversed for the lower exposures. There is no reversal for exposures which are greater than the exposure corresponding to the minimum density on the D-log h curve.

A typical D-log h curve for Eastman fine grain release positive 5302 film exhibiting the Sabattier effect can be seen on the graph on the following page. Also shown is a D-log h curve for the same film which received no second exposure.

It can be seen from the curve of the Sabattiered image that for a small first exposure there is an increasing desensitization to the second fogging exposure. This desensitization reaches a maximum for the exposure corresponding to the minimum density on the curve.

Density vs. relative log exposure



Many possible mechanisms for the Sabattier effect have been postulated in the past. The first possible mechanism that will be discussed here is that iodide in the emulsion causes the Sabattier effect. Stevens and Norrish worked with this idea and proved it wrong by using pure silver bromide emulsions and still obtaining the Sabattier effect.

Another idea that was believed to be the mechanism for the Sabattier effect was that oxidation products of the developer caused the effect. Stevens and Norrish also proved this wrong by using developers which have inert oxidation products such as hydrazine and still obtained the Sabattier effect.

Silver transfer during development is another hypothesized mechanism for the effect. Stevens and Norrish also did some work with this idea. They placed an unexposed emulsion which was soaked with developer in contact with a partially developed exposed emulsion. The two emulsions were developed in contact with each other. They found that silver was indeed transferred from the exposed emulsion to the unexposed emulsion. They concluded that this was the mechanism for the Sabattier effect.

Another hypothesis about the mechanism of the Sabattier effect is that the silver halide grains which are already developed shield the unexposed undeveloped grains from the second exposure. Marriage did some work with this idea. He exposed a photographic plate with yellow dye in it to blue light. When exposed from the front, the yellow dye absorbed the blue light hence the optical screening effect. When exposed from the front or the back the speed should decrease due to the yellow dye..Marriage also proved that the mechanism for the Sabattier effect is not totally this optical screening because he was able to produce the effect using sodium arsenite and heat for the second exposure.

The idea that the first developer produces an internal latent image which would tend to trap electrons from the second exposure was worked on by both Klotzer and Arens. Klotzer worked with a reversal first developer which he found gave a blue image.

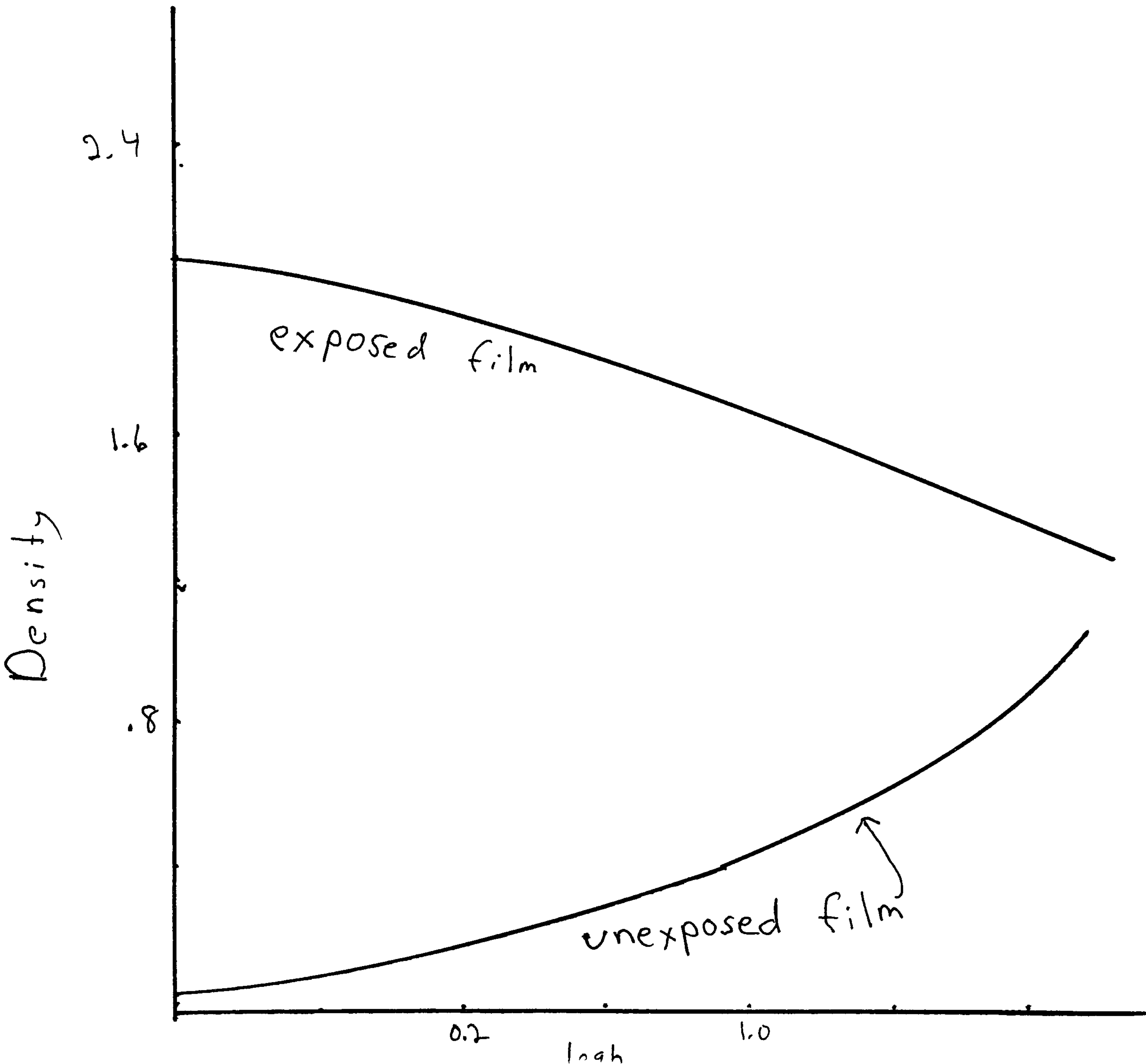
Another possible mechanism for the Sabattier effect is that there is an increasing protection against fog with increasing first exposure for small exposures Work was done on this by Couprie. He produced sulfide fog by developing the film in a surface developer and immersing it in a 10^{-4} moles per liter solution of sodium thiosulfate. He then destroyed the silver image by immersing the film in an oxidizing potassium dichromate solution. This doesn't destroy the internal fog image, so the only density remaining on the film was due to sulfide fog. His results clearly indicate that there is increasing protection against sulfide fog for small exposures.

Other proof that Couprie obtained of this action was when an unexposed film was kept in contact with an exposed film during development and then it was exposed to light One problem associated with developing the two films in contact with each other is that there is a mutual influence of the two films and the amount of protection against fog of the unexposed grains of the unexposed film depends upon the density of the sensitometric strip. This can be seen by the graph on the next page.

Another contribution to my research on the Sabattier effect was done by a student of Dr. Ronald Francis; Steven Wershing at R.I.T.. He put lauryl pyridinium bromide in developer D-19 with which he developed sensitometric strips of Tri-X-Pan film. His curves can be seen on the page following the next one. The curves obtained are similar to the Sabattier effect. The reason for this happening is that the development of the first image restrains fog from the lauryl pyridinium bromide in the vicinity.

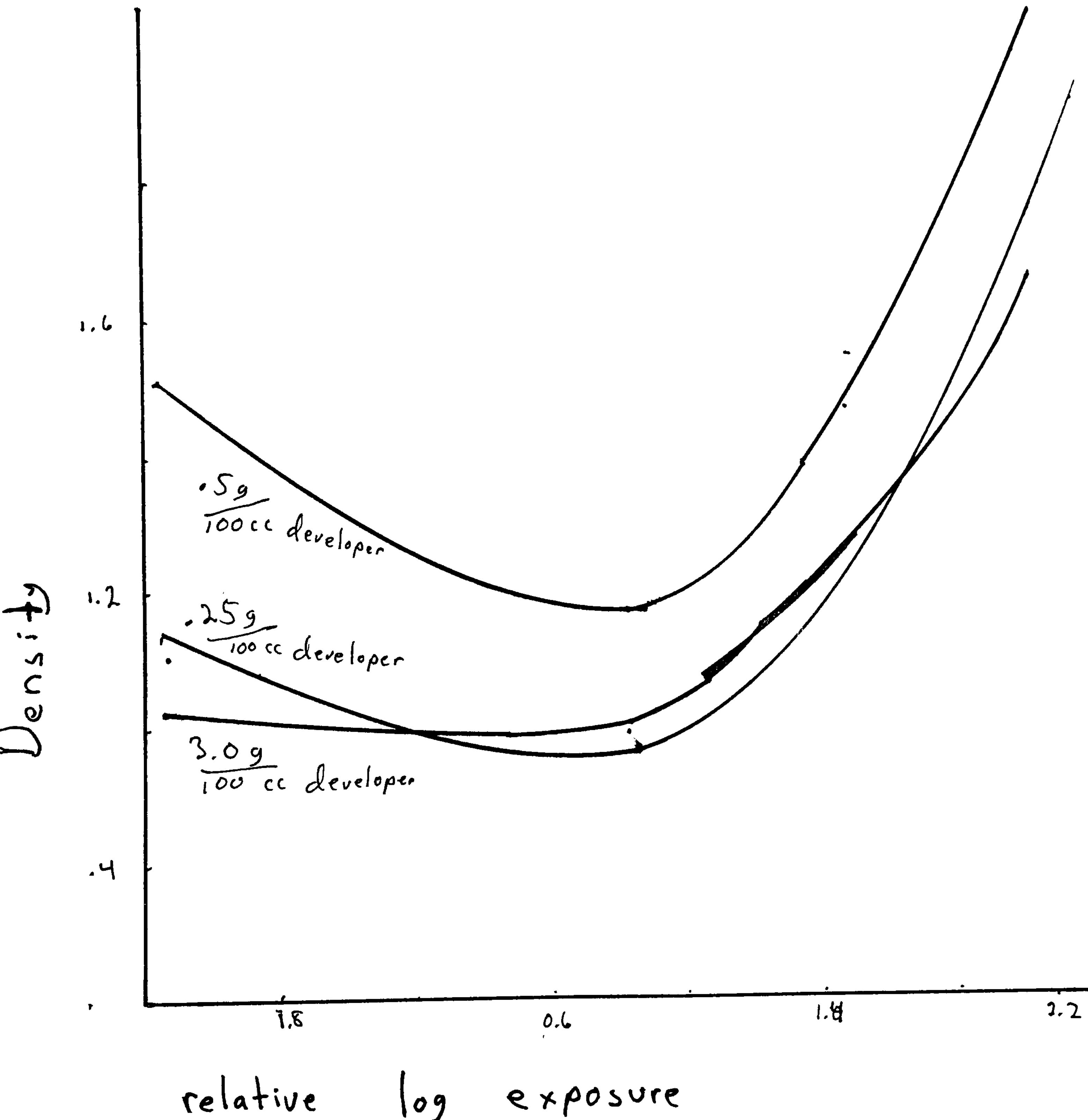
Silver transfer during development

Density vs. log exposure



Lauryl Piridinium Bromide in D-19 with Tri-x-pan film

Density vs. log exposure



In my research I attempted to find out if the unexposed grains adjacent to the developed grains are protected against reduction fog. Couprie found that the unexposed grains are protected against sulfide fog. Sodium borohydride ($NaBH_4$) which is a reducing agent was used as the fogging agent. A simple metol-sulfite-carbonate developer was used throughout the experiment and the composition of the second developer was modified to see the effects of solution-physical development and development of the internal latent image on the Sabattier effect.

EXPERIMENTAL AND RESULTS

The first thing that needed to be done was to make sure that Eastman fine grain release positive 5302 film is capable of producing the Sabattier effect. It was determined that a strong, stable, light source which would be able to produce a uniform exposure was needed so an Omega D2 enlarger was used as the fogging exposure.

The developer that was used was a simple one recommended by Dr. Carroll. Its composition is:

1) 750 ml distilled water at 52 C
2) Metol 2.50 grams
3) sodium sulfite 30.0 grams
4) sodium carbonate 50.0 grams
5) potassium bromide 1.0 grams

6) add distilled water to make 1.0 liter

The film was exposed in a sensitometer, developed for four minutes, washed, uniformly exposed to the enlarger for 10 seconds, re-developed for four minutes, fixed, washed, and dried.

The base plus fog density of the Sabattiered curve was 1.8 and the minimum density was 1.2 at step 7 for the 10 second exposure to the enlarger..

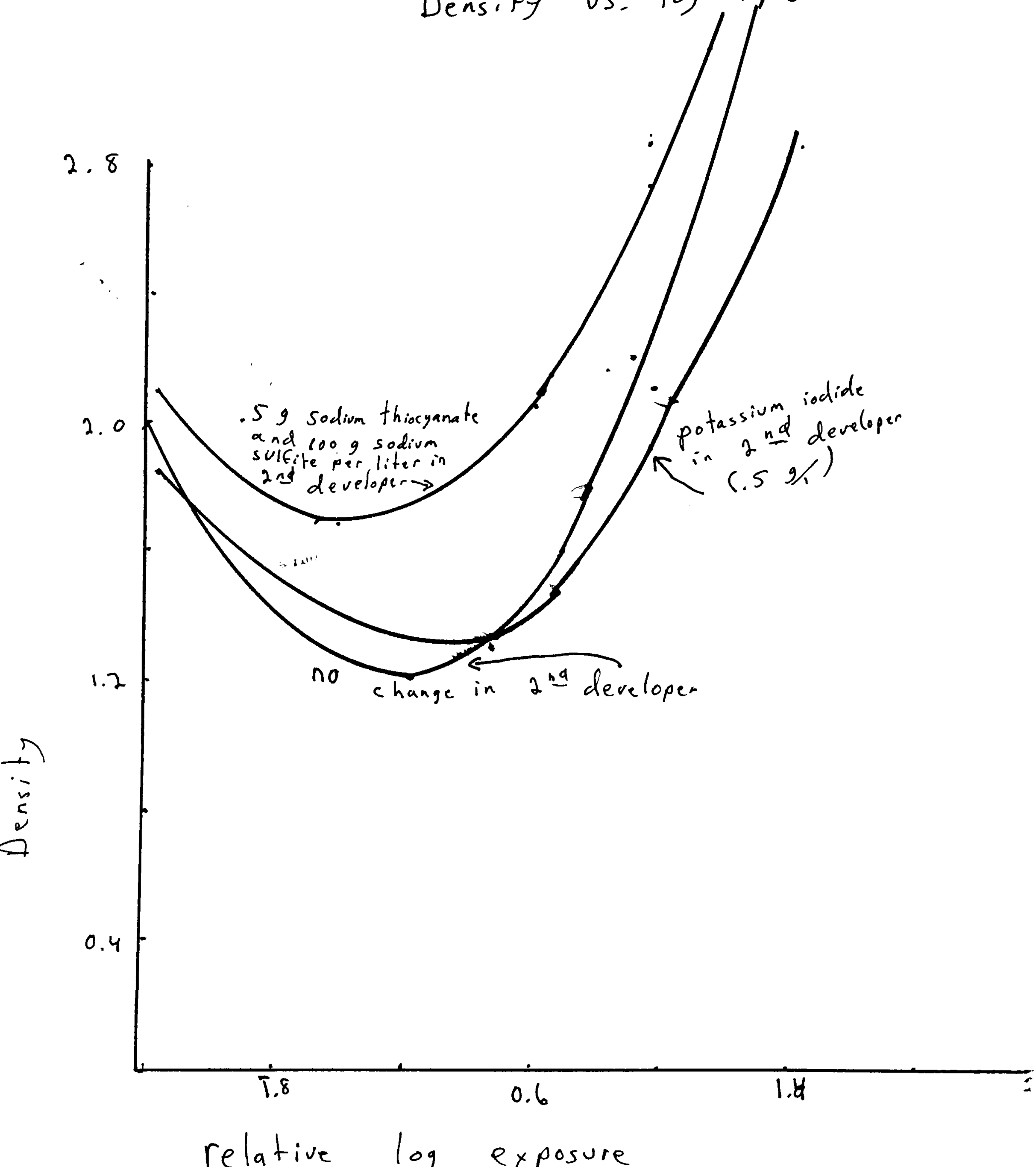
This process was also done with stop bath after the first development but the addition of stop bath had no significant effect so that step was left out for the remainder of the experiment.

The control strips (no second exposure) had a gamma (slope of the linear portion of the curve) of 1.40.

The composition of the second developer was changed to see what effects this had on the Sabattier effect. First .5 grams of sodium thiocyanate and 100 grams of sodium sulfite were substituted for the 30 grams of sulfite that were in the formula. This increased the silver solvent content of the developer which increased the amount of solution-physical development. No significant change was noticed with respect to the Sabattier effect. The minimum density was 1.8 which was 1.2 when there was no change in the second developer. However, the Sabattier effect was not significantly changed.

Effects of changing the composition of the second developer on the Sabattier effect.

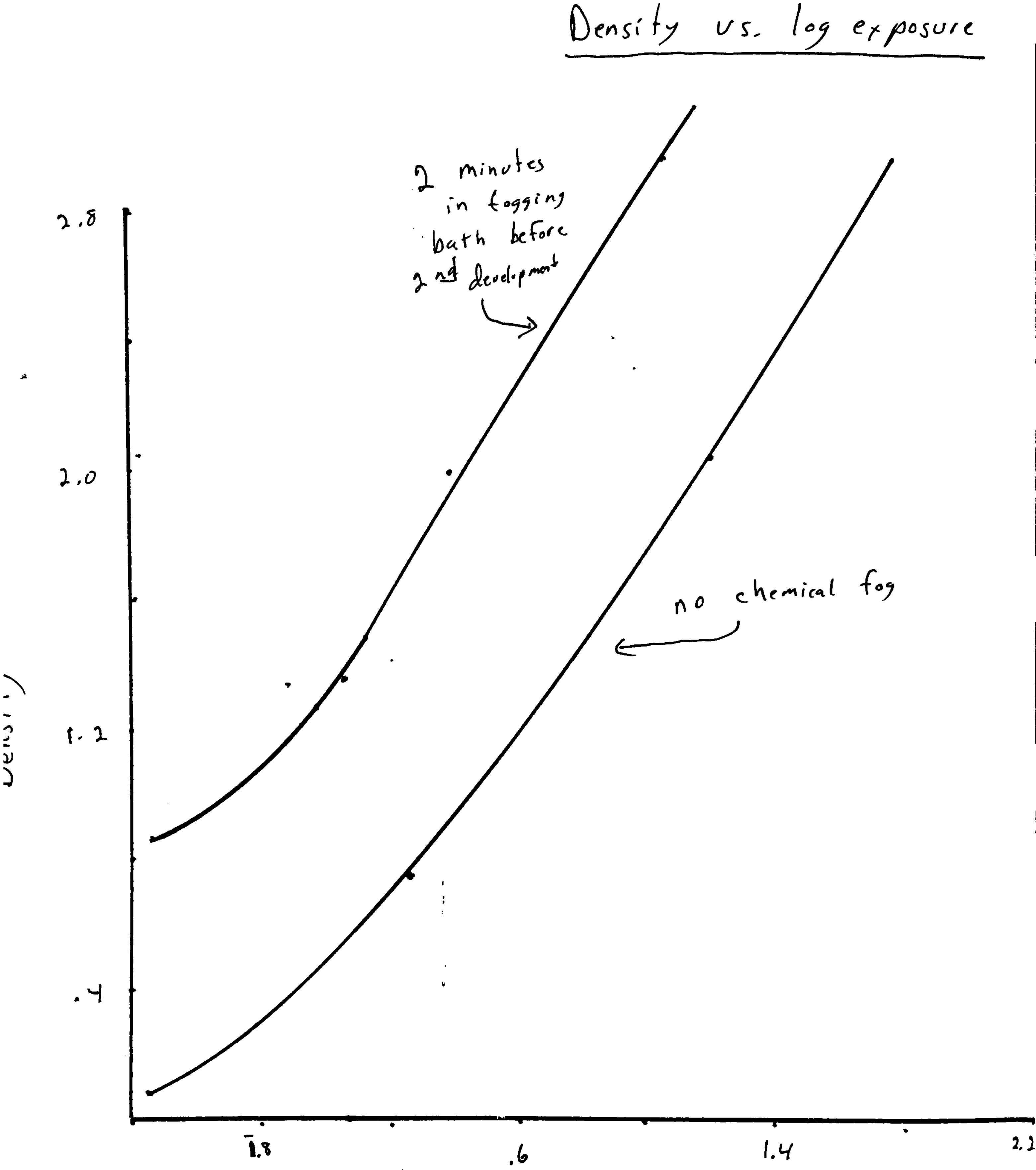
Density vs. log exposure



The second modification of the second developer was to put .5 grams/liter of potassium iodide in the developer. This breaks apart the grain so the internal latent image gets developed. This also was found to have no significant effect in altering the shape of the curve or the extent to which it was Sabattiered.

It was also desired in this experiment to substitute sodium borohydride for light in the fogging exposure. Sodium borohydride is a reducing agent, therefore it yields reduction fog. Since sodium borohydride is very unstable, it was necessary to use the fogging solution at most three hours after mixing it up. It was necessary to obtain a concentration which would uniformly fog the film but not produce so much density that the steps on the film would be undetectable. A concentration of .01 grams/liter was used.. The D log h curve of the effects of this fogging can be seen on the graph on the next page. The curve of the fogged film was parallel to the unfogged curve. Both curves had a gamma of 1.40. A fogging time of two minutes was used because it was long enough to produce a uniform density without streaking. Increasing the fogging time to five minutes did not have a significant effect. The characteristic curve of the fogged image shows no evidence of any reversal associated with the Sabattier effect. When greater concentrations of sodium borohydride were used, the density was too high to

Effect of exposing the film to chemical fog in a .01 gram per liter sodium borohydride solution after it has been partially developed.



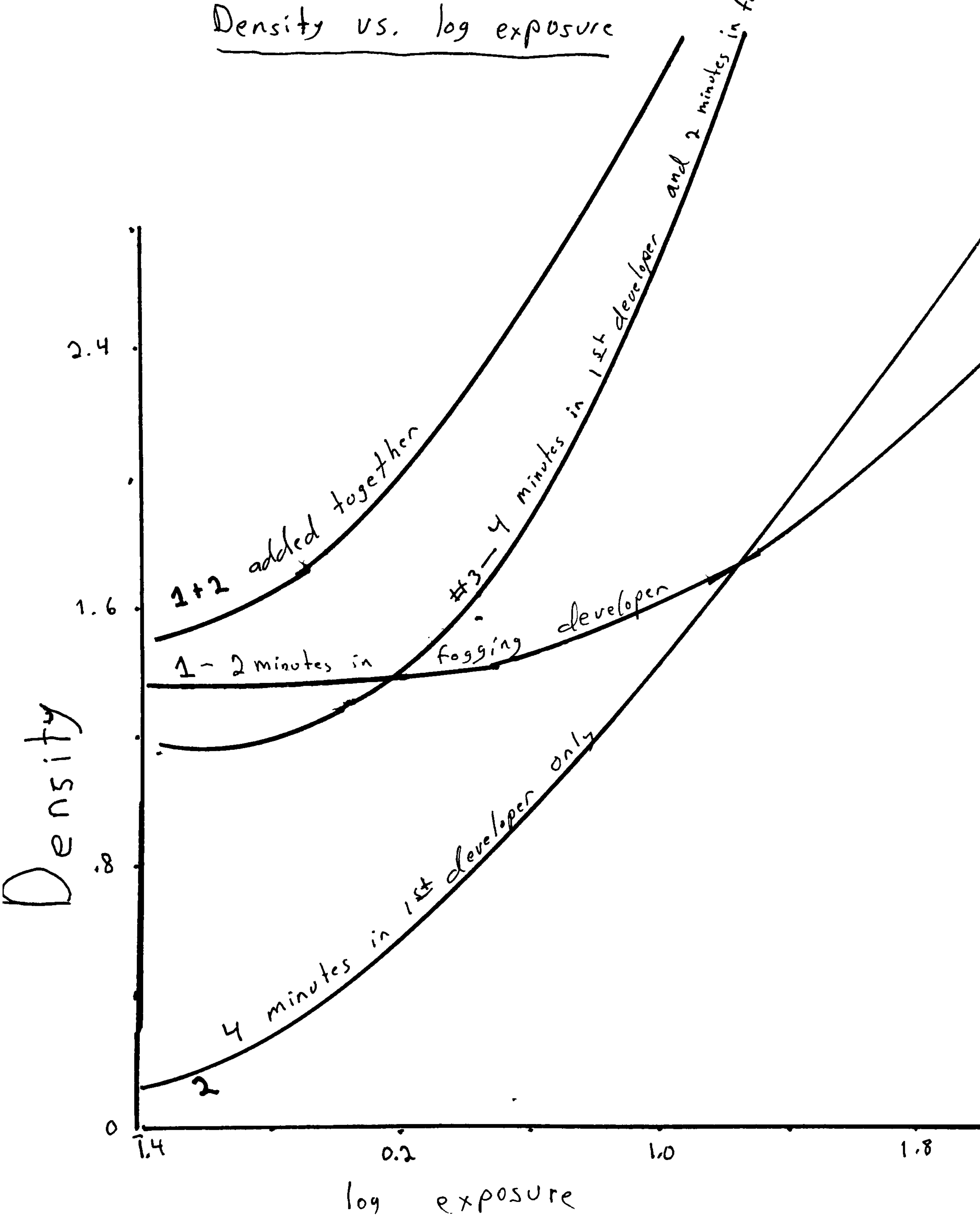
distinguish any steps, but there was once again no sign of any reversal. Sodium borohydride is a very unstable fogging agent and in all solutions that were mixed up the distilled water was boiled first to eliminate oxygen and then cooled down. The temperature of the fogging solution during processing was 68°F.

Smaller concentrations of the fogging solution were also used and there was no evidence of any reversal associated with the Sabattier effect.

The final experimental work done was to see the effects of adding .01 grams of sodium borohydride directly to one liter of developer. This developer was used as the second fogging developer. The D log h curves for this experiment can be seen on the following page. Curve #1 received only two minutes in the fogging developer. It can be seen that for low exposures the density is constant at 1.3 which suggests possible development retardation. No assumptions can be made from this graph because there is nothing significant enough to call it retardation.

Curve #3 received four minutes in the first developer and two minutes in the second fogging developer. One would think that if you added the densities from curve #1 to curve #2 which received four minutes in the first developer only, the resulting curve would overlap curve #3.

Effects of putting .01 g/liter sodium borohydride directly in to the second developer



The reason for this is that there is more silver to be developed in the two strips from curve#1 and curve#2 than in curve #3.

DISCUSSION

My results from working with reduction fog show no evidence of any Sabattier effect while Couprie, who worked with sulfide fog got curves which show a distinct reversal for low exposures. This indicates that sulfide fog and reduction fog are two completely different types of fog which are affected differently. Couprie also bleached out the silver image leaving only fog. This was not done in my experiment because I was able to get a uniform density that was not too high that it would be impossible to distinguish one step from another.

I learned that with the Sabattier effect it is quite difficult to get repeatable results because there are so many variables and care must be taken to keep everything constant. The fogging agent was quite difficult to get repeatable results with. The closest that I was able to come to repeatability was .2 density units.

Couprie stated in his paper that the silver solvent content of the developer affected the degree of the Sabattier effect since it affects the amount of silver transferred. In my experiment, when the silver solvent concentration of the second developer was changed the shape of the curve was not changed significantly.

CONCLUSION

In this experiment, I found no evidence that increasing protection against fog is the mechanism of the Sabattier effect. The Sabattier effect using the enlarger light as the second exposure was not influenced by increasing the amount of solution - physical development or breaking apart the grains to develop the internal latent image in the second developer.

When a sodium borohydride solution was substituted for light as the second exposure a higher density was produced for all exposures but there was no evidence of any reversal. Adding the sodium borohydride to the second developer did not make the film show any sign of the Sabattier effect. In this experiment, I learned that chemical fog and light are two completely different types of exposures. After analyzing my results I have come to the conclusion that we are still far away from discovering the mechanism of the Sabattier effect.

A good idea for future experimentation would be to use a surface developer with ascorbic acid rather than sodium sulfite as the preservative to minimize the solution-physical development.

Also, it would be interesting to do some more work using sodium arsenite and heat as the second exposure as Marriage did.

ACKNOWLEDGEMENTS

I would like to thank Dr. Schumann for helping me obtain equipment throughout the year. I wuold also like to thank Mohamed Abouletta for always helping me get into locked rooms. I would also like to thank Mike Bauman for letting me use his typewritter to type this thesis. Finally but most importantly I would like to thank my advisor, Dr. Burt Carroll, for his invaluable advice and assistance and constant encouragement and without whom this thesis would not have been possible.

REFERENCES

1) Stevens and Norrish-- Photographic Journal Volume 77 (1937) page 20 , Volume 78 (1938) page 513, Volume 79 (1939) page 27

2) Mees and James - The Theory Of the Photographic Process - third edition

3) S. Couprie - Influence of Development on the Properties of Non-exposed Grains. The Journal of Photographic Science- May/June 1972 Volume 20 #3

4) Solarization - S. Walker and C. Rainwater 1974 Amphoto

5) Dr. B.H. Carroll - personal communication