Title: **Frozen in Time: Preserving the Daguerreotype Latent Image.**

Authors: ***John Hurlock and Eric Rickart***

Introduction

Throughout the history of the daguerreotype, the ephemeral nature of the latent image has been a recognized limitation of the process. [1-4] In his American Handbook of the Daguerreotype [2], S.D. Humphrey advises that; "If practicable, it is most expedient that the plate be submitted to the action of mercury immediately on coming from the camera." Humphrey acknowledges that; "I have frequently, however, carried plates for miles in the plate-holders and after exposing in the camera, brought them back to expose to mercury, and obtained fair proofs; but for the reason before given, it is advisable to carry along the bath, and bring out the impression on the spot".

In the mid-19th century when daguerreotypists were principally involved with studio portraiture work, delayed development and attendant problems of latent image fading were relatively minor issues. Daguerreians in the 19th century had observed an increase in speed of aged plates as early as 1847, according to comments made by Alexander Beckers at a meeting of the Society of Amateur Photographers of New York in 1889 [23]. Not all 19th century reports are completely credible however. Alexander Hesler of Galena Illinois claimed that he made instantaneous exposures with a shutter driven by a rubber band. In 1889, he revealed that his secret was coating his plate's weeks before use. [24] "The longer they were kept, the more rapid they became. They could be exposed and developed anytime in the future." One could conclude from this statement that the latent images on well-aged daguerreotype plates lasted almost indefinitely. Most contemporary daguerreians would dispute this claim.

Although contemporary daguerreotypists are faced with the same technical problems with the medium, most have goals that are much more ambitious than those of their 19th century counterparts and they often are interested in working under primitive conditions far from the studio. Unlike most modern photographers, the contemporary daguerreotypist has always had to make several difficult decisions when operating outside his studio. The first decision is whether to use Becquerel or mercury development. Choosing Becquerel development eliminates the need to carry along a mercury developing apparatus and its attendant fume disposing equipment. With the Becquerel method, the plate holder can be covered with Rubylith. When the slide holder is withdrawn, the image development can be monitored in full daylight. While this is indeed a useful technique, the slow speed of iodized plates makes them ill suited to portraiture and certain outdoor scenes with people, animals, or windy conditions.

On the other hand, if the daguerreotypist chooses to use multiply sensitized plates, he can make the exposure, and then hurry back to his darkroom and mercurialize the plates, before the latent image fades into oblivion. If the weather is cool and dry, the daguerreotypist might have a leeway of several hours and still get an acceptable image.

On the other hand, if the temperature and/or the humidity were high, the latent image might be spoiled in less than one hour.

Purpose

Anyone who has made daguerreotypes has experienced the frustration of having to delay the mercury development of an image, only to discover that the developed image has subsequently faded or that spots and other ghostly apparitions have appeared on the plate. The authors set out to test the hypothesis that moisture and excessive storage temperature are largely responsible for this image deterioration.
According to generally accepted photographic theory, either thermal dissociation and/or the oxidation of latent image silver atoms are responsible for latent image fading in almost all silver halide images. Whether the photolytic silver atoms, which make up the latent image, are destroyed by excessive heat or moisture, their useful life might be extended if the exposed plates are stored at both a low temperature and low relative humidity.
The purpose of our research project was to test the effect of a number of factors on latent image stability. Our goal was to extend the life of the latent image and reduce any attendant image defects so that daguerreotypists using mercury development would have new means to photograph scenes far away from their darkrooms without the necessity of bringing along their developing apparatus.

Initial Trials

Eric Rickart began making daguerreotypes with the primary goal of producing images of wilderness landscapes. Initial attempts, involving delayed development of plates held at ambient temperature and humidity for several hours following exposure, resulted in failed images. Following a simple assumption that the chemical reactions responsible for latent image fading might be temperature dependent, he used dry ice to reduce the temperature at which plates were stored after exposure in the field. To prevent moisture condensation, plates (in their plate holders) were sealed in plastic bags along with silica gel desiccant before placing them on dry ice. This proved to be a successful technique, and good images were often obtained on plates that had been stored for several days prior to standard warm mercury development. The image in Plate 1 is an early example that was developed 3 days after exposure.

Plate 1. Angel's Landing, Zion Nat'l Park, Washington Co., Utah. 4x5 daguerreotype taken Feb 14 and developed Feb 17, 1999. E. A. Rickart

Although cold storage does appear to be an effective method to delay development of daguerreotype plates, controlled experiments were needed to actually understand the effects of temperature, humidity and time on the latent image. The following experiments were designed and conducted by John Hurlock.

EXPERIMENTAL RESULTS

EXPERIMENT 1: IMAGE FADING AT VARIOUS TEMPERATURES

All four daguerreotypes in Plate 2 were fumed for 10 seconds over iodine then 10 seconds over bromine and finally for 5 more seconds over the iodine at approximately 20 C. The final color of the plate was a dark rose color typically used by modern daguerreians.[17] After the camera exposure, all plates except the control plate were immediately sealed in recloseable plastic bags containing silica gel. After the appropriate storage period, the refrigerated plates were allowed to warm to room temperature for approximately 30 minutes. Then each plate was developed for 3 hours at 20C under a 50 torr vacuum. The plates were not gilded.

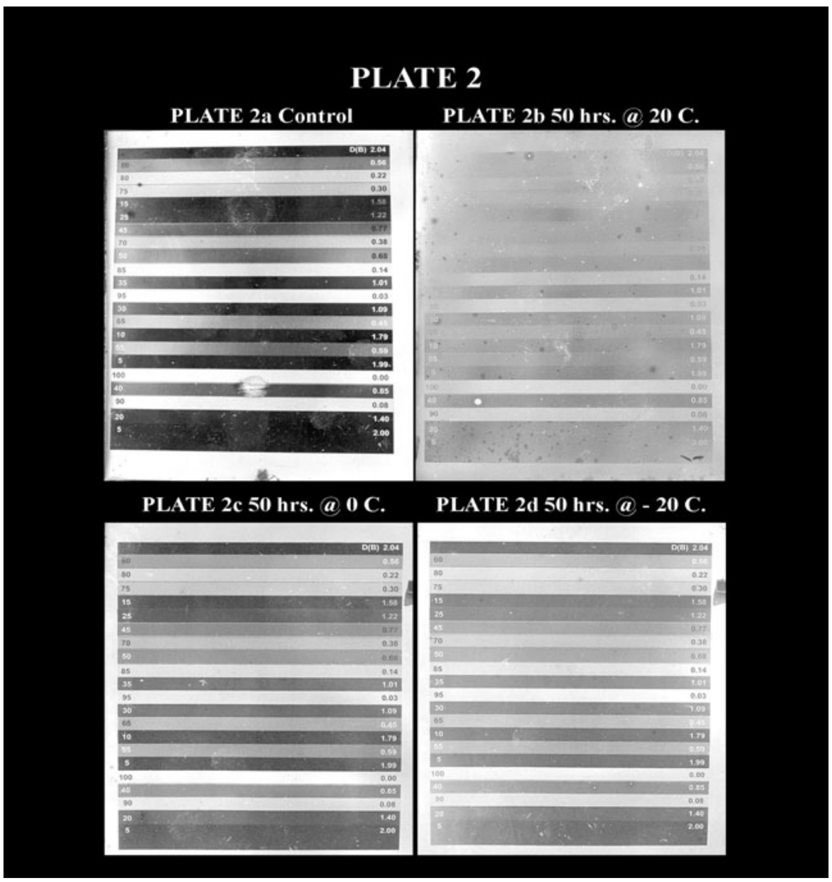
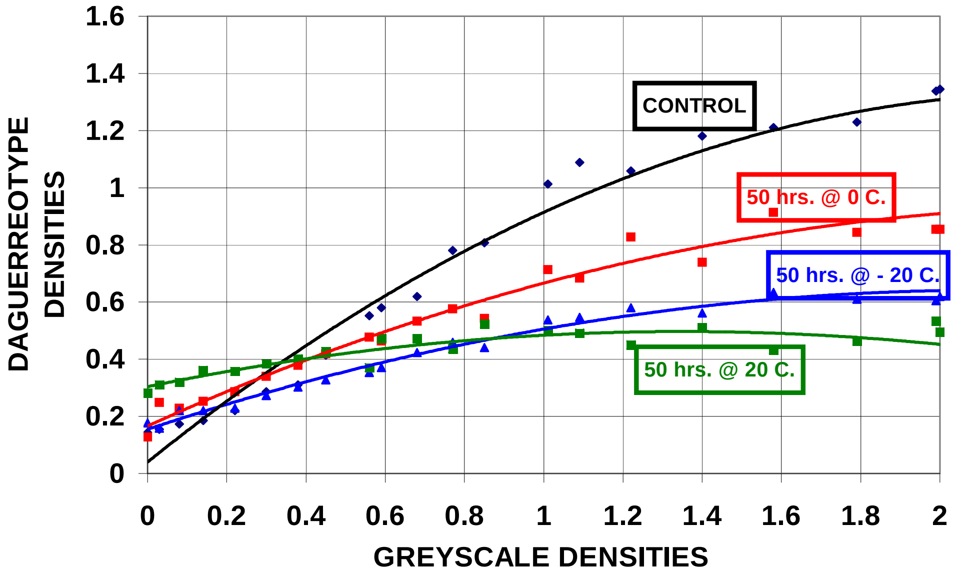


TABLE I

Image	Storage Conditions		Result	Image Characteristics		
	Temp	Time		Highlights	Shadows	Contrast
Plate 2a	20 ^{0} C	0 hours	Good	Strong	Dark	Excellent
Plate 2b	20 ^{0} C	50 hours	Very Weak	V. Weak	Foggy	Flat
Plate 2c	0 ^{o} C	50 hours	Minor fading	Acceptable	Acceptable	Good
Plate 2d	- 20 ^{0} C	50 hours	More fading	Weak	Swirls*	Low

*Image swirls, water condensation.

FIGURE 1
DENSITY OF DAGUERREOTYPE PLATES
HELD AT VARIOUS TEMPERATURES BEFORE DEVELOPMENT
VS GREYSCALE DENSITY



SUMMARY OF RESULTS

These results indicate that while cooling the plates may have a very beneficial effect on latent image stability, the damaging effect of moisture on the image appears to be a more severe problem. The control plate 2a, which was developed within 15 minutes, had a strong image with dark shadows and excellent contrast. After 50 hours at room temperature, plate 2b had only a very weak flat image with extensive fog in the shadow areas. After 50 hours at 0 C, plate 2c still had an acceptable image. On the other hand, plate 2d, which was held at an even lower temperature (–20 C), had a weak image that contained swirls. This condition occurs when there is water condensation on surface of the cold plate before development. This points out the need for more care to avoid exposing cold plates to humid air.

EXPERIMENT 2: IMAGE FADING WITH THINNER COATINGS

The silver halide salts on the surface of the daguerreotype plate apparently have a tendency to absorb water from the air in humid conditions. This experiment was conducted to determine if the plates with thinner coatings (less silver halide) on their surface would absorb less moisture. The hope was to reduce moisture damage to the latent image.

Therefore, all four daguerreotypes in Plate 3 were fumed for only 6 seconds over iodine then 6 seconds over bromine and finally for 2 more seconds over iodine. The final color of the plates was a pale rosy straw color used mainly for landscapes by daguerreians. After a camera exposure, all plates except the control plate were stored in recloseable plastic bags in the freezer at –20C. After the appropriate storage period, each plate was allowed to warm to room temperature for at least an hour before removing them from their sealed bags. The last plate in the series was also warmed with a hair dryer to speed the warming process. Then each plate was developed for 3 hours at 20C under a 50 torr vacuum. The plates were not gilded.

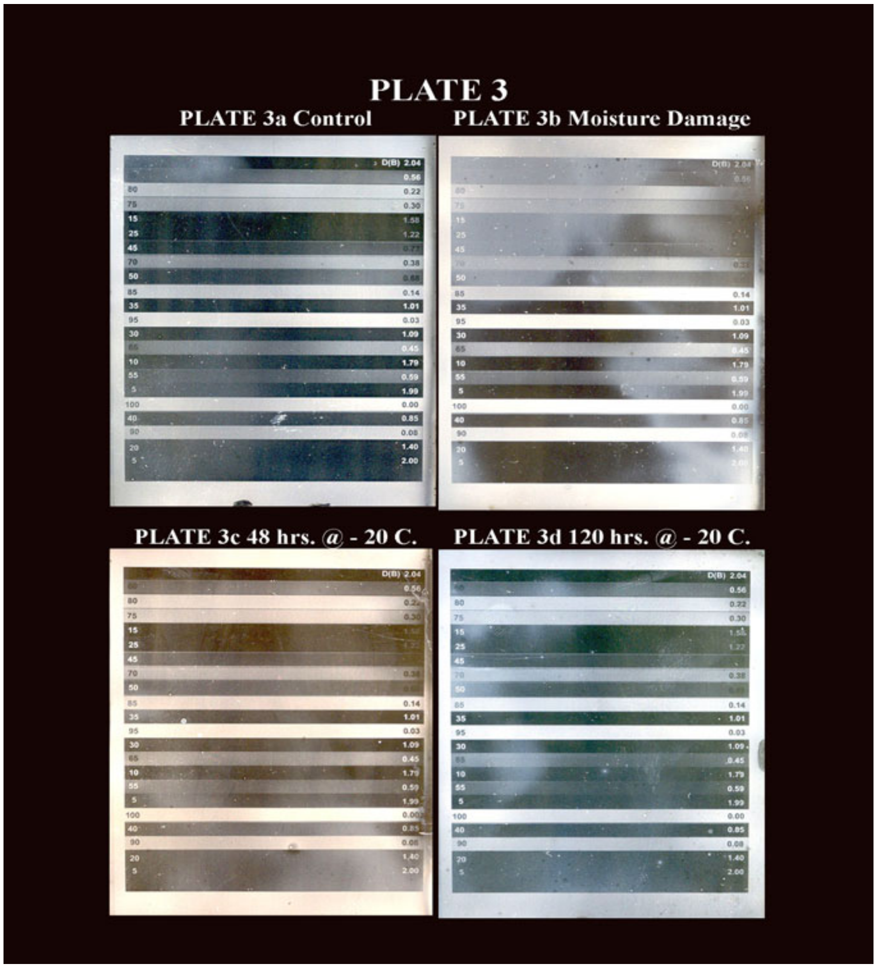
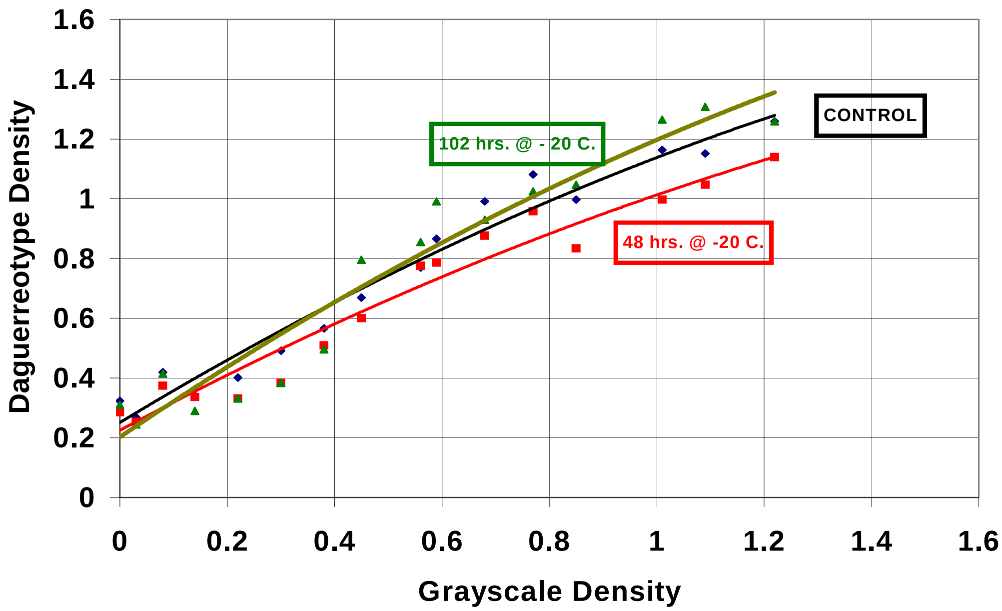


TABLE II

Image	Storage Conditions		Result	Image Characteristics		
	Temp	Time		Highlights	Shadows	Contrast
Plate 3a	20 ^{0} C	0 hours	Good	Strong	Dark	Excellent
Plate 3b	- 20 ^{0} C	48 hours	H2O damage	Uneven*	Uneven*	Uneven*
Plate 3c	- 20 ^{0} C	48 hours	sl. damage	Strong	Uneven	Good
Plate 3d	- 20 ^{0} C	120 hours	v. sl. damage	Acceptable	Uneven	Good

*Image swirls, water condensation.

FIGURE 2
DENSITY OF THINLY COATED DAGUERREOTYPE PLATES HELD AT - 20 C. BEFORE DEVELOPMENT vs GRAYSCALE DENSITY



SUMMARY OF RESULTS

The more thinly coated plates in this series of experiments appeared to be less affected by the moisture in the air. The control plate 3a, which was developed within 15 minutes, had a strong image with dark shadows and excellent contrast. After 48 hours at -20 C, plate 3c, still had a strong image with good contrast. However the shadows still contained some swirls, indicating water condensation on surface of the cold plate before development. Plate 3d, which was also heated to accelerate the warming process, still had a strong image with good contrast after 120 hours at –20 C. While the shadow areas were darker, they still contained a few moisture swirls.

The persistence occurrence of moisture damage on plates that had been sealed with desiccant in recloseable bags indicates that there may be a potential problem with this method. If the initial relative humidity of the air is very high, sufficient time must be allowed for the desiccant to absorb the moisture in the bag. Otherwise, when the bags are cooled, the relative humidity in the chilled air may exceed 100%, allowing condensation on the plate surface. This could pose a problem if the temperature is also high since the latent image has a limited lifetime at higher temperatures and the plates must be cooled quickly to preserve it.

EXPERIMENT 3: VACUUM STORAGE TO REDUCE MOISTURE DAMAGE

As in the previous experiment all of the daguerreotypes in Plate 4 were fumed for 6 seconds over iodine then 6 seconds over bromine and finally for 2 seconds over iodine once more. The final color of the plate was the same pale rosy straw color used in the 2nd group of experiments. To keep them dry after the camera exposure, all of the plates, except the control plate in this experiment were stored at – 20 C, in a vacuum desiccator over silica gel under a vacuum of 10 torr.

Each plate was allowed to warm up for approx. 1.5 hours with some warming via a hair dryer, before the desiccator was opened so that the temperature of the plates was above the dew point. Due to the long warm-up time, the plates suffered only slight moisture damage when they were transferred to the mercurizer. Each plate was developed for 3 hours at 20C under a 50 torr vacuum. To compare the images to those of typical daguerreotype images, all of these daguerreotypes were eventually gilded.

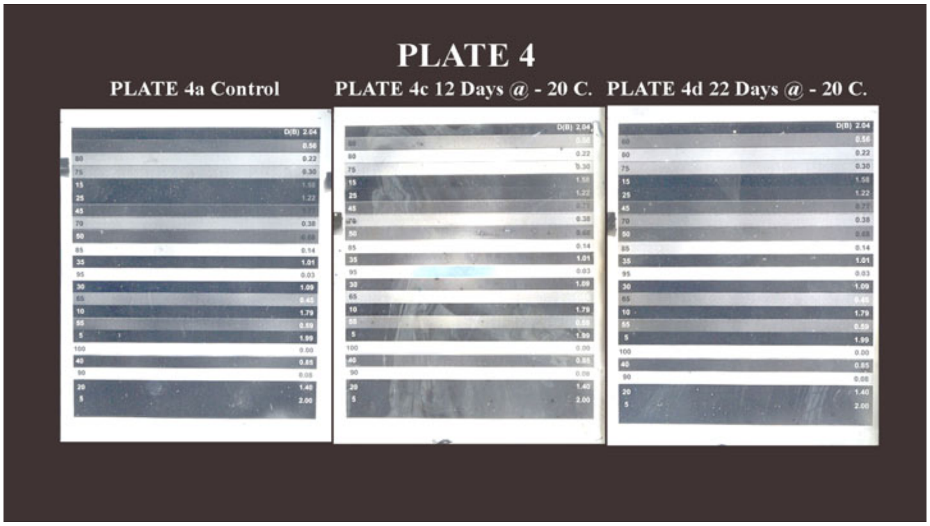
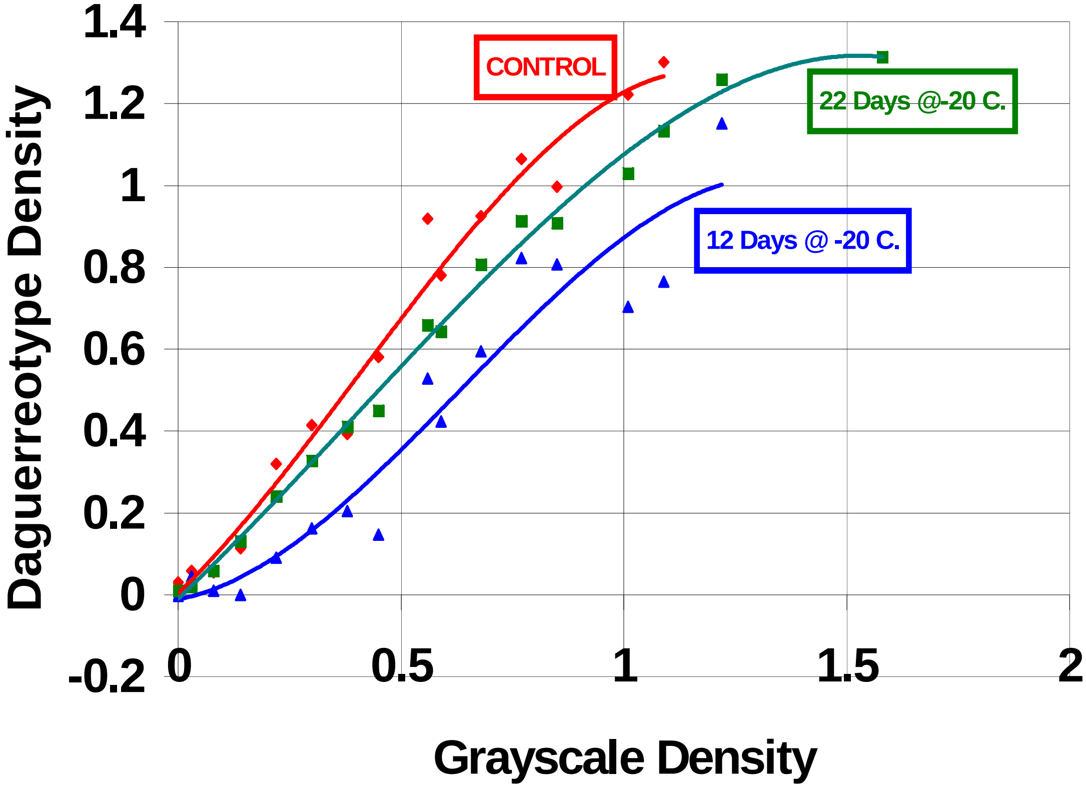


TABLE III

Image	Storage Conditions		Result	Image Characteristics		
	Temp	Time		Highlights	Shadows	Contrast
Plate 4a	20 ^{0} C	0 hours	Excellent	Strong	Dark	Excellent
Plate 4c	- 20 ^{0} C	12 days	Acceptable	Solariz’d	Acceptable	Acceptable
Plate 4d	- 20 ^{0} C	22 days	Good	Strong	Dark	Good

FIGURE 3
DENSITY OF GILDED DAGUERREOTYPES
vs GRAYSCALE DENSITY



SUMMARY OF RESULTS

Rigorous exclusion of moisture from the surface of the plates immediately after exposure appears to have improved the image characteristics of the daguerreotypes significantly. As anticipated, the control image in plate 4a had strong highlights, dark shadows and excellent contrast. The second plate was scratched by the slide of the plate holder during exposure and thus was not evaluated. The third image, plate 4c, was slightly solarized. As a result, it appeared to have slightly darker highlights and lower contrast after 12 days at -20 C. However, the forth image in plate 4d had strong highlights, dark shadows, and a contrast only slightly less than that of the control plate after 22 days at –20C. The outcome of this experiment appears to indicate that the latent images of the daguerreotype may be kept for several weeks at temperatures below freezing if the plates are kept very dry.

EXPERIMENT 4: EASY METHOD FOR VACUUM STORAGE OF PLATES

Using a vacuum desiccator to store exposed plates is not a very practical solution for extending the latent image of daguerreotypes. However a more convenient alternative may be available. Food products are typically vacuum-sealed for improve freshness and extended storage life. The Tilia corporation markets a BagVac® appliance for home use. This appliance will seal almost anything under a 19-inch vacuum (ca 250 torr), in heavy walled plastic bags. Why not a daguerreotype plate?

For this experiment, a set of four quarter plates was fumed together for 15/10/5 seconds over I/Br/I under approx 1fc of light at approximately 18 ^{o} C. A 3rd I fuming of 2 sec was done under a safelight. A second set of 2 quarter plates was fumed together in a manner identical to the above group of 4 plates.

All plates were aged for approx. 2 hours and then exposed to a grayscale illuminated by 2-#2 blue photofloods approx. 15 inches from the gray scale. Incident illumination was approximately 40 foot-candles.

After exposure, each plate was vacuum –sealed, together with a DRIERITE® desiccant bag, in it’s plate holder, in a Foodsaver® plastic bag. Two of the sealed bags were then placed in a refrigerator @ 0 ^{o} C and two were placed in a freezer @ - 20 ^{o} C. After storing for a period of 5 days to 4 weeks, the bags were removed from cold storage. The bags containing the plates were allowed to warm to room temperature for 1 hour. The second set of 2 plates was stored at room temperature (20 ^{o} C) for 1 to 2 days. After removing the plates from the bags, each plate was then developed for 2 hours over room temperature mercury under a vacuum at 50 torr. After development each plate was fixed and dried.

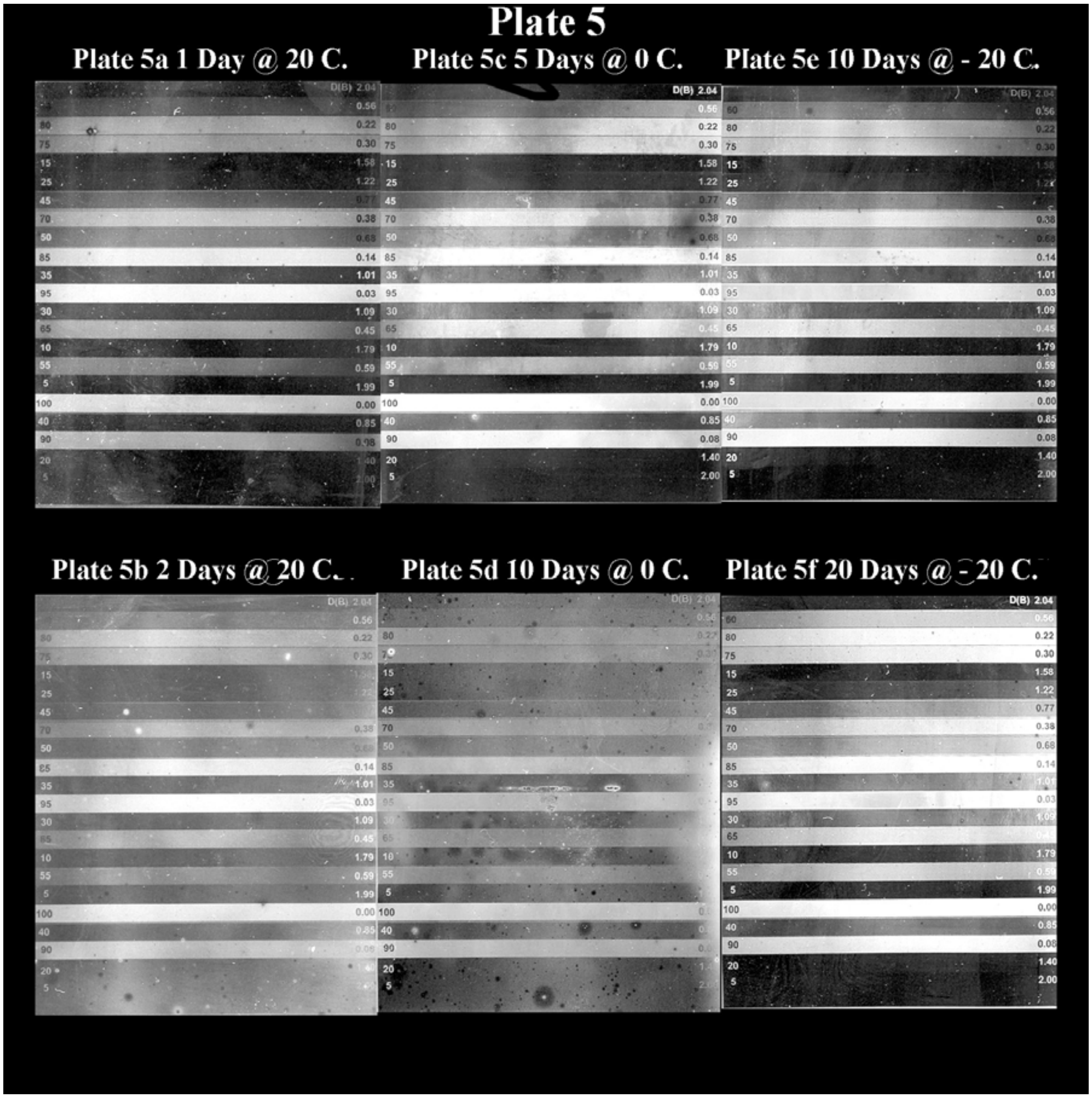
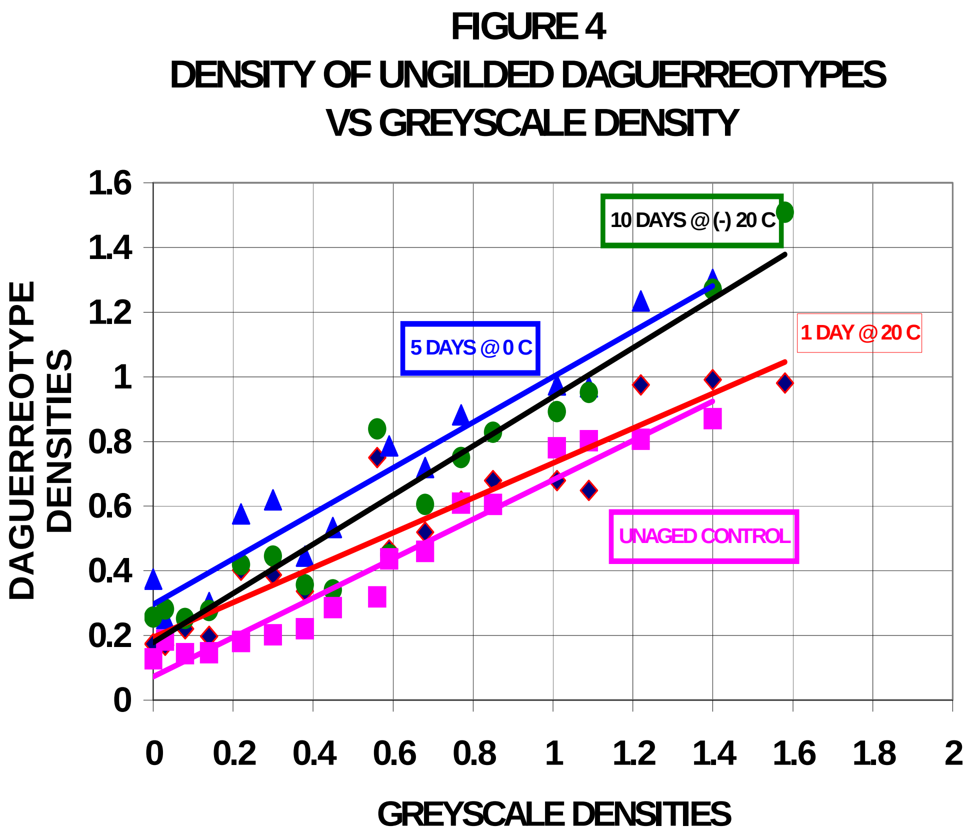


TABLE IV

Image	Storage Conditions		Result	Image Characteristics		
	Temp	Time		Highlights	Shadows	Contrast
Plate 5a	$20\ ^{0}$ C	1 day	Excellent	Strong	Dark	Excellent
Plate 5b	$20\ ^{0}$ C	2 days	Faded	Acceptable	Foggy	Flat
Plate 5c	$0\ ^{o}$ C	5 days	Excellent	Strong	Dark	Excellent
Plate 5d	$0\ ^{o}$ C	10 days	Weak	Weak	Foggy	Flat
Plate 5e	$-20\ ^{0}$ C	10 days	Excellent	Strong	Dark	Excellent
Plate 5f	$-20\ ^{0}$ C	20 days	Good	Strong	Acceptable	Good



SUMMARY OF RESULTS

Vacuum –sealing exposed plates in Foodsaver® plastic bags immediately after exposure appears to preserve the image characteristics of the daguerreotypes from the damaging effects of moisture in the environment.

Plates stored at 20 ^{o} C appeared to retain good images for about 1 day. Plate 5a, aged for 1 day, had strong highlights, dark shadows and excellent contrast but plate 5b, stored for 2 days, appeared noticeably faded with foggy shadows and a flat contrast.

Plates stored at 0^{o} C retained better images for approximately 5 days. Plate 5c, aged for 5 days, still had strong highlights and dark shadows, but plate 5d, aged for 10 days, had a weak image with foggy shadows and flat contrast.

Plates stored a –20 ^{o} C retained excellent images for at least 10 days. Plate 5e, aged for 10 days, still had strong highlights, dark shadows and excellent contrast. Even after 20 days, plate 5f still had strong highlights, and acceptable shadows, and good contrast. The results of this experiment appear to confirm that the latent images of exposed daguerreotype plates will keep for several weeks at temperatures below freezing when they have been vacuum-sealed in Foodsaver® plastic bags.

USING VACUUM-SEALED BAGS TO STABILIZED LATENT IMAGES

A series of 4X5 daguerreotype plates were fumed for 15/10/5 seconds over I/Br/I under approx 1fc of light at approximately 18 C. A 3rd I fuming of 2 sec was done under a safelight. Each plate was allowed to age for approx. 2 hours before exposure. The plates were then used to take a series of landscape images. In the field, the exposed plates were temporarily stored in recloseable bags with silica gel. Ambient temperature in the field ranged from 20 to 40 F (-5 to +5 C). The plate holders containing the exposed plates, were vacuum-sealed in Foodsaver® plastic bags, together with a 3 gram packet of DRIERITE®. For storage at ambient temperature, a small drop of mercury wrapped in a piece of filter paper was also inserted in the plate holder along with the plate. After storage, the plates were allowed to warm to room temperature, if necessary, before developing. All plates were developed for 2 hours at 20C under a vacuum of 50 torr. After developing, the plates were fixed dried and gilded.

The image in plate 6 was stored in an evacuated Foodsaver® plastic bag with mercury at room temperature for 24 hours before developing. A faint image of the sky, due to partial mercury development, was observed when the plate was removed from the bag

Plate 6. Willow Springs forest. 4x5 Daguerreotype of taken Jan 11 and developed over cold mercury at 50 torr on Jan 12, 2002. J.R.Hurlock

The image in plate 7 was stored in an evacuated Foodsaver® plastic bag for 5 days at 0 C before mercury development.

Plate 7. Lake Katherine Falls. 4x5 Daguerreotype taken Feb 12 and developed over cold mercury at 50 torr on Feb 17, 2002. J.R.Hurlock

The image in plate 8 was stored in an evacuated Foodsaver® plastic bag for 10 days at -20 C before mercury development.

Plate 8. Sawmill Creek, 4x5 Daguerreotype taken on Jan 13 and developed over cold mercury at 50 torr on Jan 23, 2002. J.R.Hurlock

THE EFFECTS OF TEMPERATURE AND HUMIDITY

Our experiments have demonstrated that the useful life of the latent image of the Daguerreotype can be extended to as long as 3 weeks providing that the plate is kept in a dry environment. If the relative humidity is high, it appears that plates with thinner silver halide coatings retain their latent image longer than more heavily coated plates.

Plates sealed in bags along with a small amount of mercury appear to retain their latent image longer. This method also causes a partial development of the latent image that can be fully developed at a later time.

Low temperature facilitates the preservation of the latent image on stored plates. If the plates are to be cooled to temperatures below the wet bulb or dew point temperature of the surrounding air, it is important to seal them in a dry container before they are cooled to minimize the condensation of moisture on their surface.
Similarly, it is equally important to allow them to warm up to the ambient temperature before re-exposing them to a humid environment. We have developed practical approaches to achieving these conditions.

MINUMUM CONDITIONS FOR STABILIZING LATENT IMAGES

The needs of the average daguerreian would be met if he/she could extend the life the latent image for 1 to 24 hours under a wide range of conditions. Under ideal ambient conditions, where the temperature and humidity are low – say 10 C (50 F) and 30% RH- The latent image of the daguerreotype can easily be expected to remain strong for several hours if the plate is sealed in a recloseable plastic bag with desiccant. However, these conditions can be expected only during the cooler months of the year.
If the daguerreian practices in one of the dryer areas of the Western United States, he/she may still expect good results after 24 hours with only moderate cooling of the plates after exposure. If longer delays are expected, more rigorous cooling of the sealed plates with dry ice will extend the life of the images for several days or weeks. The images in plates 9 through 12 were taken during the course of one trip and were developed after storage for between 2 to 8 days with dry ice.

Plate 9. Devil's Kitchen, Colorado Nat'l Monument, Mesa Co., Colorado. 4x5 Daguerreotype taken Feb 16 and developed on Feb 24, 2002. E. A. Rickart

Plate 10. Red Canyon, Colorado Nat'l Monument. 4x5 Daguerreotype taken Feb 16 and developed on Feb 24, 2002. E. A. Rickart

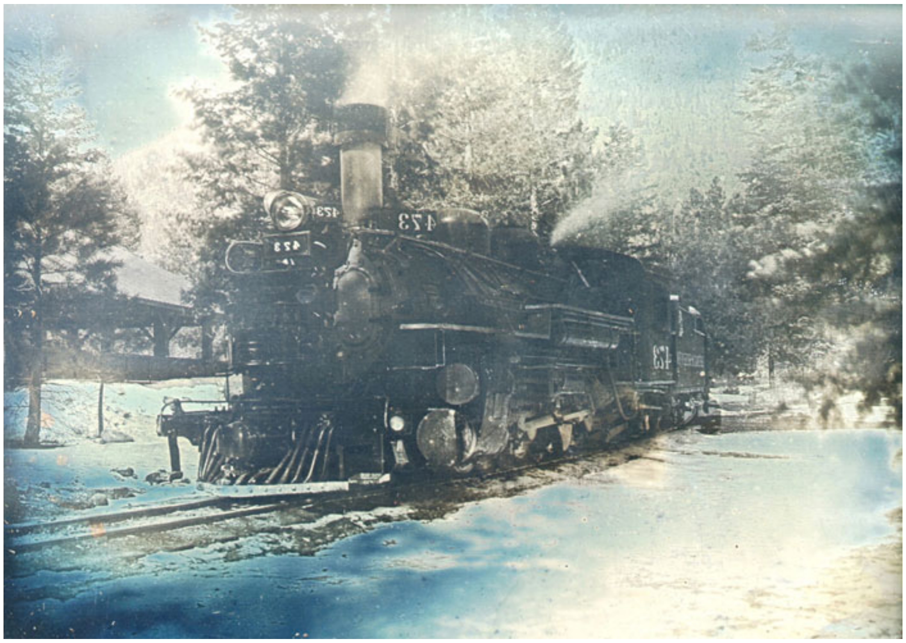


Plate 11. Locomotive, Cascade Canyon, La Plata Co., Colorado. 4x5 daguerreotype taken Feb 19 and developed on Feb 24, 2002. E. A. Rickart

Plate 12. San Francisco Peak from Sunset Crater, Coconino Co., Colorado. 4x5 Daguerreotype taken Feb 22 and developed on Feb 24, 2002. E. A. Rickart

If the daguerreian practices under hot and/or humid conditions, the latent image may not last more than an hour unless more extensive preservation conditions are employed. Rapid cooling or freezing of the exposed plate, even in a recloseable plastic bag, before the desiccant has absorbed the moisture therein will frequently cause moisture damage to the image. Under these conditions, quickly removing the moisture-laden air from the bag containing the plate has been shown to reduce damage and improve image quality.

USEFUL LATENT IMAGE LIFE	**STORAGE TEMPERATURE**	**AMBIENT HUMIDITY**	**STORAGE CONTAINER**
15 MINUTES	80 TO 100 deg F	50 TO 100%	NONE
1 HOUR	68 deg F	30 TO 50%	RECLOSEABLE BAG
24 HOUR	68 deg F	20 TO 30 %	RECLOSEABLE BAG
5 TO 10 DAYS	32 deg F	20 TO 30%	RECLOSEABLE BAG
5 TO 10 DAYS	32 deg F	50 TO 100%	FOODSAVER BAG
SEVERAL WEEKS	0 deg F	20 TO 20%	RECLOSEABLE BAG
SEVERAL WEEKS	0 deg F	50 TO 100%	FOODSAVER BAG

EQUIPMENT FOR PRESERVING THE DAGUERREOTYPE LATENT IMAGE

The easiest method appears to be to seal the plates in their holder in a recloseable plastic bag together with a small amount of silica gel or calcium sulfate (DRIERITE®) desiccant. One disadvantage of this method is that sufficient time must be allowed for the moisture trapped in the bag to be absorbed by the desiccant before the plate is cooled to avoid condensation within the bag.

More rapid removal of moisture and shorter plate thawing times can be achieved by using a commercially available vacuum-sealing device such as the Tilia Inc. Foodsaver® system. The disadvantages of this technique are the added equipment required and the reliance on an electrical power source.

Tilia's Foodsaver BagVac® appliance is available from Wal-Mart for less than $100
The BagVac® is capable of evacuating approximately 2/3^{rds} of the air (i.e., 250 torr) and then heat–sealing a plate holder containing a Daguerreotype plate in a heavy walled plastic bag in less than a minute.

Plate holder vacuum-sealed in Foodsaver bag for cold storage.

If you are traveling by automobile, you can purchase a DC to AC power inverter which can be connected the vehicle’s battery. A 400 watt inverter which can be purchased from Walgreen’s drugstores (Maxx, model VEC024) or Heartlandamerica.com (No. VI-66014) for $49.99, is sufficiently powerful to run the Foodsaver bag sealer.

ACKNOWLEDGMENTS

The authors thank Charlie Schreiner and Irv Pobboravsky for reviewing earlier drafts of this paper and offering many constructive comments toward its improvement. The technique for spontaneous mercury development during storage is based on one of Irv’s earlier innovations. We are particularly grateful to him for suggesting this method.

ABOUT THE AUTHORS

JOHN HURLOCK has been a member of the Daguerreian Society since 1996. He is a retired chemical engineer and has been making Daguerreotypes off-and-on since 1958. His last article “The Light at the end of the Bromine” appeared in the Daguerreian Annual in 2000.

ERIC RICKART has been a member of the Daguerreian Society since 1995. He has been making daguerreotypes since 1993, and often uses delayed development. A professional zoologist, he is Curator of Vertebrates at the Utah Museum of Natural History in Salt Lake City.

NOTES

1. N. P. Lerebours. A Treatise on Photography, translated by J. Egerton, London, Longman, Brown, Green, and Longmans, 1843, pp. 194-195.

2. S. D. Humphrey. American Hand Book of the Daguerreotype, 5th edition, New York, S. D. Humphrey, 1858, p. 38.

3. K. E. Nelson. A Practical Introduction to the Art of Daguerreotypy in the 20th Century. Northlight, volume 2, Tempe, AZ, Arizona State University, 1977, p 16.

4. G. Meegan. "Becquerel-development in a new light". The Daguerreian Annual, 1991, p 165.

5. T. H. James, "Some Effects of Environment on Latent Image Formation". Photographic Science and Engineering, Volume 14, Number 1, January-February, p84-88 (1970)

6. W.F. Berg and H. E. Keller Photographic Science and Engineering, Volume **11:** p178 (1967)

7. G. Abouy and H. Faraggi, J. Phys. Radium Vol. 10: p105 (1949)

8. K. B. Mather, Phys Rev. Vol. 76. P486 (1949).

9. G. Tleuberganova. Vestnik Akad. Nauk Kazakh. SSSR Vol. 12 Number 8 p93 (1956

10 B. Markow, Photographic Science and Engineering. Vol. 9 p353 (1965)

11. T. H. James, F. E. E. Germain, and J. M. Blair. J. Phys. Chem. Vol. 38 p1211 (1934)

12. W. C. Barron, and A. W. Wolfendale. British J. Appl. Phys. Vol. 8, p297 (1957).

13. G. Leide, Arkiv. Phys. Vol. 11 p329 (1956), Vol. 22 p147 (1962).

14 B. I. Kazantsev and P. W. Meiklyar, Zh. Nauchn. I Prikl. Fotogr. I Kinematogr, Vol. 3, p401 (1958.

15. A. L. Kartuzhanskil and A. FG. Kurchenko, Zh. Nauchn. . I Prikl. Fotogr. I Kinematogr, Vol. 11 p294 (1966).

16. Beiser, Phys. Rev. Vol. 80: p153 (1951).

17. W. Lohmann, Z. Naturforsch, Vol. 11a: p592 (1956)

18. W Halg, and L. Jenny Helv. Phys. Acta, Vol. 24: p508 (1951). Vol. 25: p733 (1952).

19. H. W. Mejer, Z. Wiss, Photo, Vol. 53: p46 (1958),

20. K. M. Romanovskaya, and K. B. Bogomolov, Usp. Nauch. Vol.12: p36 (1956)

21. Schreiner, Charles "Iodine and Bromine: Part 1, It Takes Two to Tango" The Daguerreian Annual 1998 (Lake Charles, LA) By the Daguereian Society (1998) p165-174.

22. J. Hurlock "Warming Up to Cold Mercury" The Daguerreian Annual 1998 (Lake Charles, LA) By the Daguerreian Society (1998) pp. 230-240

23 A Beckers "Fifteen Years' Experience of a Daguerreotyper" The Daguerreian Annual 1993 (Green Bay, Wisconsin) By the Daguerreian Society (1993) pp. 118

24. Newhall, Beaumont, "The Daguerreotype in America", Dover Publications, New York, NY. (1975) P 124-125

APPENDIX A

Mechanisms of Latent Image Decay

Due to the relatively unprotected location of its silver halide coating on the surface of a silver plate, the Daguerreotype is extremely prone to latent image fading. However, the fading of the Daguerreotype image is not unique among photographic materials. In his comprehensive survey article on the effects of environment on the latent image, [(5)] T.H. James, then of the Kodak Corp Research Laboratories, cited that there was general agreement that latent image fading in silver halide emulsions is accelerated by increasing relative humidity and retarded by lowering the temperature.

There was however some disagreement as to the exact cause of this fading. Early articles attributed fading to re-halogenation or recombination of the silver atoms with free iodine or bromine for example [(6).]

$$\mathbf{Ag + Br \rightarrow Ag^{+}\ Br^{-}}$$

Other researchers [(6-10)] have attribute fading to oxidation of the silver atoms in the latent image in the presence of moisture.

$$2\ \mathbf{Ag + O + H_2O \rightarrow}\ 2\ \mathbf{Ag^{+}\ 2\ OH^{-}}$$

Still others researchers [(11-15)] concluded that oxygen was not involved because the fading occurred at about the same rate in nitrogen and argon as it did in oxygen.

Some proposed [(16-17)] that the fading is due to thermal dissociation of silver atoms back into silver ions (i.e., salts) plus an electron.

$$\mathbf{Ag \rightarrow Ag^{+} + e}$$

According to James [(5)], different researchers may have reached different conclusions either because they used different silver halide emulsions in their experiments, or they failed to control humidity while controlling temperature for example.

James, Germain, and Blair [(11)] reported that the ratio of the difference between the partially faded image density D at time t, and the completely faded image density at the infinite time t_∞, to the density of the initial un-faded image D (initial) can be approximated by the following expression:

$$(1)\qquad \mathbf{\frac{(D - D_\infty)}{D\ (initial)} = e^{-k(t - t_\infty)}}$$

Halg, Jenny, [(18)] and Meir [(19)] reported that latent images produced by short exposures to high intensity light faded faster than images produced by longer exposures to lower intensity light. They proposed that the larger latent image centers, which were produced by longer exposures, were more stable because they were more resistant to oxidation, than the smaller image centers produced by shorter exposures. Since both the latent image centers and the final images of the Daguerreotype appear to be extremely small, one might assume that they also were very susceptible to fading by oxidation. One might also assume that the latent image of the highlights of the Daguerreotype, which contain a high density of relatively smaller image centers, would fade more rapidly than the shadows of the Daguerreotype, which contain larger more irregularly shaped image centers. Thus, contrast, as well as solarization in the Daguerreotype image might be expected to decrease, under conditions where the development has been delayed.

Romanovskaya and Bogomolov [20] found that fading time t_f, for a fraction f of the latent image, was a product of a constant A_f raised to the exponential power of the ratio of a humidity factor U, divided by a temperature factor **kT.**

(2) $$t_f = A_f^{\exp(+U / kT)}$$

In "The Daguerreotype in America",[24] Newhall reported that even "Daguerreotypists noticed that the relative humidity of the air affected sensitivity."

APPENDIX B

EXPERIMENTAL PROCEDURE

Step 1 Four pre-polished, quarter-plate size daguerreotype plates were taped together on a sheet of acrylic plastic approximately the size of a whole plate. The plates were then given a final buffing with a velvet-covered paddle. Then the four plates were simultaneously sensitized by fuming first over iodine and then over bromine. A final 2-second iodine fuming was conducted under a safelight so as not to expose the surface to actinic light. The sensitized plates were removed from the acrylic plastic block and loaded into separate plate holders.

Step 2 The plates were usually held for 15 to 30 minutes before exposure. To determine whether the sensitivity of the plates changed after preparation, some plates were allowed to age at room temperature for a specific time before the next step.

Step 3 Each plate in the series was given an identical camera exposure to a grayscale.

Step 4 The plate holders containing the plates to be aged were usually placed in sealed recloseable plastic bags together with fresh desiccant. Alternately, some plate holders were stored with desiccant, but no mercury, in a clean glass, vacuum desiccator at approximately 10 torr. Still other plate holders were vacuum-sealed, together with a desiccant bag, in Foodsaver® plastic bags with a Tilia Inc. BagVac® appliance.

Step 5 Plates were stored at room temperature (approx. 20 C), or in a refrigerator at approx. 0 degrees C, or in a freezer at approx. –20 degrees C.

Step 6 After a pre-determined storage period which varied from 24 hours up to several weeks, the plates were removed from cold storage and allowed to return to room temperature for at least one hour before they were removed from their sealed containers.

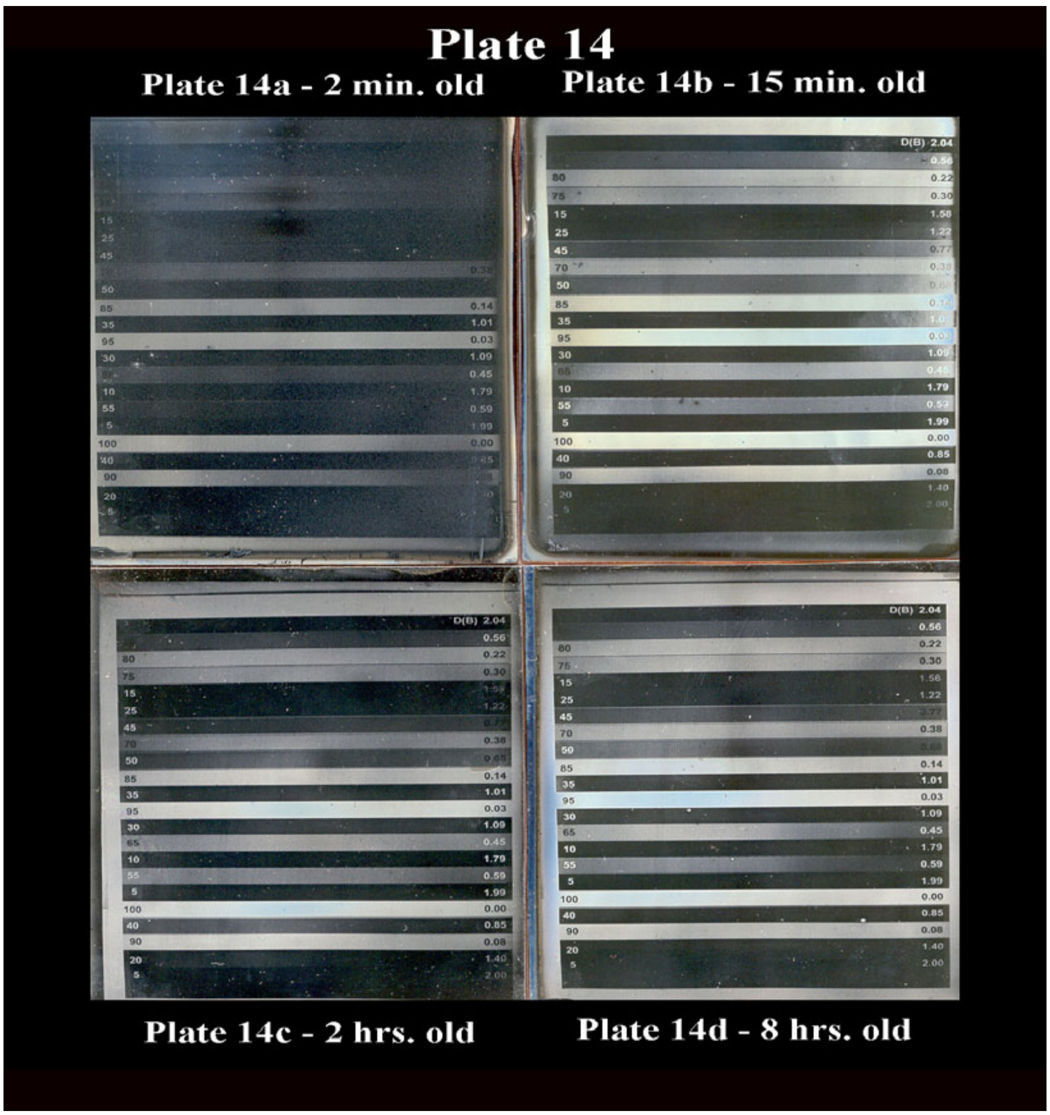
Step 7 Within a given series of plates or block of experiments, all the plates were identically developed over room temperature mercury [18] under a vacuum of 50 torr. One control plate in each block was usually developed immediately after exposure. After developing, each plate was then fixed and dried. Some plates were gilded so that the image characteristics more closely matched those of a typical daguerreotype.

Step 8 All daguerreotypes were scanned together with a calibrated grayscale using an HP® Scan jet 5370C scanner. Relative image densities of each grayscale step on the daguerreotypes were estimated using the eyedropper tool in the info palette of Adobe® 4.01. The L values were matched with the corresponding L value on the grayscale scan to obtain the density. Image densities were then plotted versus the density of the original grayscale using Excel®.

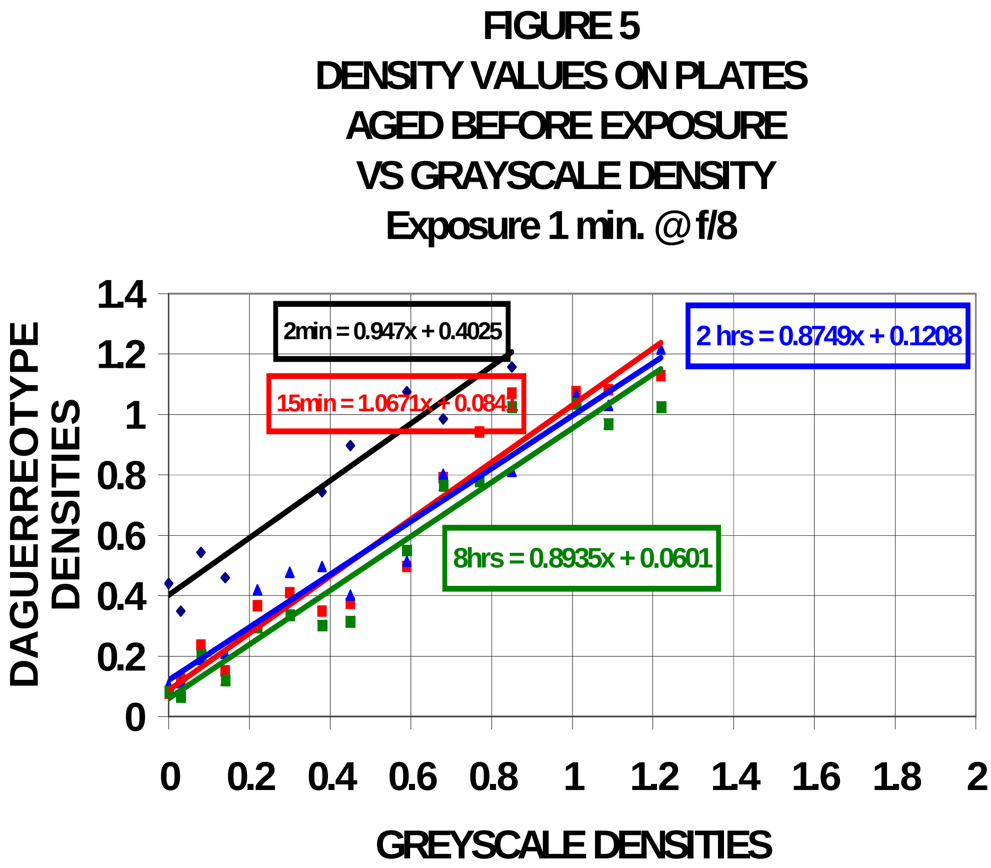
APPENDIX C

SENSITIVITY CHANGES IN DAGUERREOTYPES PLATES AFTER COATING

Four quarter plates were fumed simultaneously for 15/10/5 seconds over I/Br/I under approx 1fc of light at approximately 18 C. A 3rd I fuming of 2 sec was done under a safelight. The plates were exposed 2 min, 15 min, 2 hours, and 8 hours after coating to a grayscale illuminated by 2-#2 blue photofloods approx. 15 inches from the gray scale. Incident light was 40 foot-candles. Plate 14 shows the 2 min. plate (Plate 14a), the 15 min. plate (Plate 14b), the 2-hour plate (Plate 14c), and the 8-hour plate (Plate 14d). To avoid any latent image fading, plate development was begun within 5 minutes after exposure.



The results in Figure 5 indicate that the sensitivity of a Daguerreotype plate increases rapidly during the first 15 minutes after coating and reaches a plateau within 2 to 8 hours after the fuming process.



R Shlaer had previously observed a similar increase in the sensitivity of Daguerreotype plates. Shlaer reported that Daguerreotype plates reach their maximum speed approx. 15 min. after coating.

Bands with similar densities on the un-aged plate (2 min.) vs. the aged plates (15 min to 8 hrs.) were exposed to grayscale bands that were 0.4 units brighter. The data confirms that the aged plates were slightly more than twice as sensitive to light as the freshly prepared plate.

APPENDIX D

EFFECTS OF STORAGE TEMPERATURE ON LATENT IMAGE DECAY

The photolytic silver atom of the latent image must overcome a thermal barrier in order to recombine with halide. The energy level or the thermal barrier that a reacting molecule, such as a silver atom, must overcome is called the activation energy of that reaction. An activation energy can be visualized as a thermal fence that the silver atom must leap over before it can react. If the temperature is higher, more silver atoms will reach this higher energy level and therefore more can be expected to react. After this reaction takes place, there will be fewer photolytic silver atoms around to form image particles. Then, when development finally takes place, the image density will be proportionally lower

A reaction between two chemicals such as a photolytic silver atom and a halogen molecule, which are in equal concentration may be characterized as a pseudo 1st order reaction. This means that the rate at which the reaction takes place will be proportional to the concentration of the photolytic silver atoms present on the daguerreotype plate.
The rate of this reaction can be approximated by the expression,

$$d\,Ag / dt = k_1 (Ag_{initial} - Ag_{final})$$

Assuming that image density is proportional to the concentration of photolytic silver atoms, we can also write this expression in terms of the step tablet densities,

$$d\,D / dt = k_1 (D_{initial} - D_{final})$$

The rate constant for this reaction can be calculated from the expression,

$$k = \frac{1}{t} \times -\ln \frac{(D_{initial} - D_{final})}{D_{initial}}$$

The rate constant k in sec-1 varies with the temperature according to the Arrhenius equation:

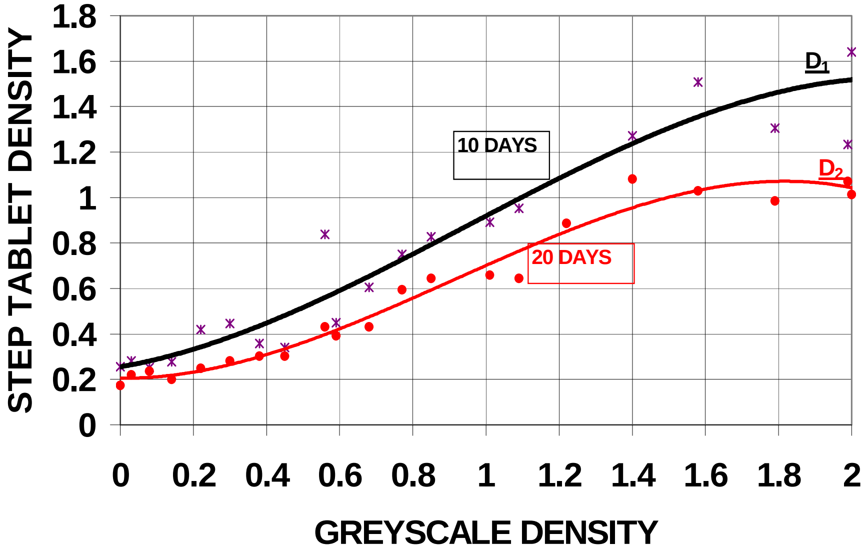
$$\frac{d \ln k}{dT} = \frac{E^*(\text{activation energy})}{RT^2}$$

When integrated this equation becomes:

$$\ln k = \frac{-E^*}{RT} + \text{a constant}$$

The step plate densities before and after aging were plotted versus the grayscale density (Figure 6).

FIGURE 6
STEP TABLET DENSITY LOSS
AFTER AGING FOR 10 TO 20 DAYS @ - 20 C.
VS GREYSCALE DENSITY



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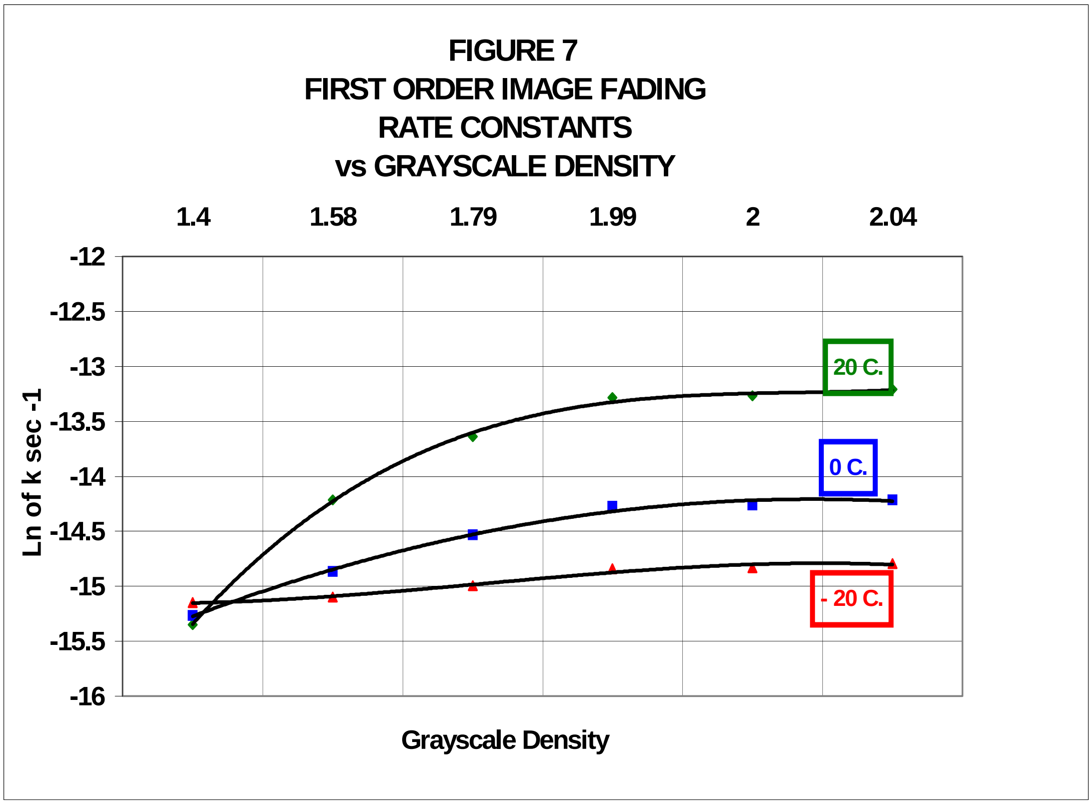
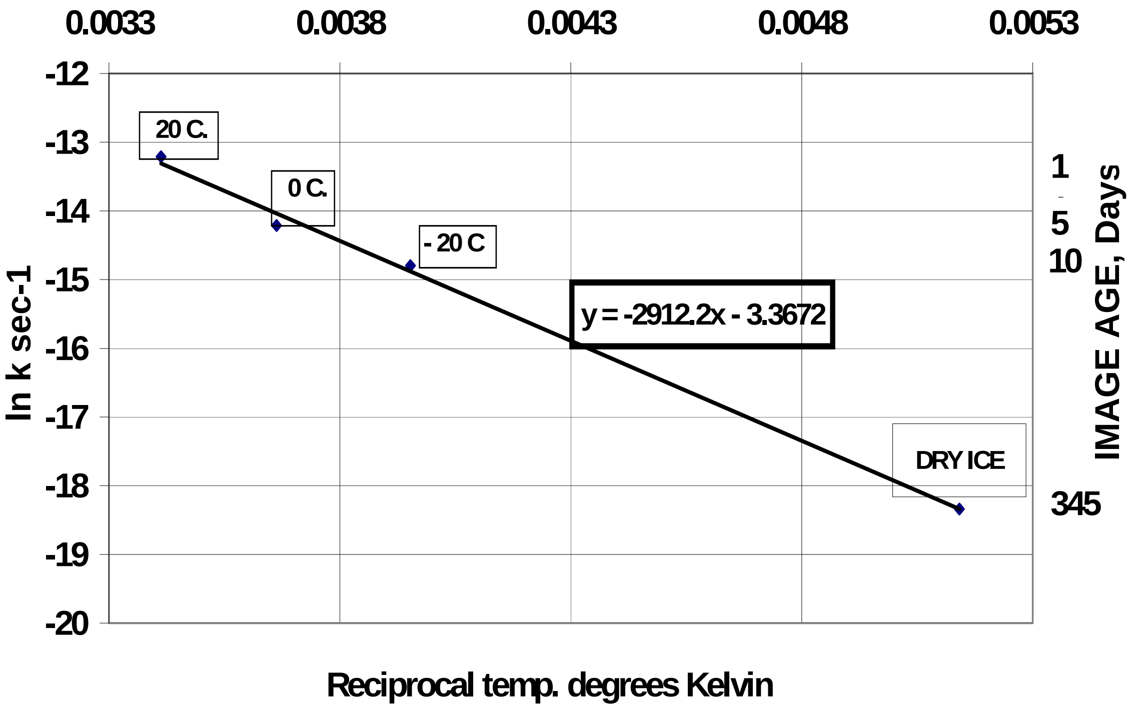
The value of k $_1$ was then calculated from the difference in densities $\mathbf{D}_1$ minus $\mathbf{D}_2$ for all three storage temperatures. Then the natural log of k $_1$ was then plotted versus the density of the grayscale chart. (Figure 7)



While the value of ln k_1 appeared to be dependent upon the initial value of the density of the step, ln k_1 appeared to plateau as the grayscale density approached 2. In Figure 8, the maximum value of ln k_1 was subsequently plotted vs. the corresponding reciprocal temperature (in degrees Kelvin). The result was a straight line.

FIGURE 8
LATENT IMAGE FADING RATE CONSTANTS
vs RECIPROCAL TEMPERATURE
Activation Energy E* = 2912(1.987) = 5786 calories



From the Arrhenius equation, the slope of this straight line (-2912) was multiplied by the ideal gas constant (1.987 calories, deg K-1) to obtain an activation energy of 5786 calories for latent image fading. By extrapolating this line to the reciprocal of the temperature of dry ice (194.5 degrees Kelvin) a value for ln k of -18.34 can be estimated. The corresponding value of the rate constant k_1 ,1.084E -08 was only 1/35 th of the value of k at -20C. Therefore we might assume that daguerreotype plates stored in dry ice, will keep their image 35 times longer than plates stored in a freezer at -20C or approximately 345 days.