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Effects of Aqueous Treatment on Albumen Photographs

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Abstract

Current conservation practice often calls for aqueous surface cleaning, unmounting and washing of albumen photographs. This research is intended as an assessment of this common treatment technique which was a logical adaptation from paper conservation and photographic processing. Data are presented so that the conservator can better balance the possible benefits of aqueous treatment against the drawbacks. The results of this study show that any aqueous treatment, be it surface cleaning or immersion, increases the cracking of the albumen layer while not substantially altering albumen yellowing.

This study is based upon the controlled aqueous treatment of a group of twenty mounted and never-mounted albumen photographs. Print color, gloss, and albumen cracking were measured before and after treatment with water. Color data shows that surface cleaning and immersion are not effective in altering image discoloration. Measurements of crack width and population were made by comparing microphotographs of cracks taken before treatment, after surface cleaning, and after immersion. All albumen prints exhibit some form of cracking prior to treatment. The pre-existing cracks in albumen photographs increase in width after surface cleaning and again after aqueous immersion. The number of cracks in a given area increases after treatment. The measurement of gloss before and after treatment shows that most prints decrease in gloss after treatment.

1. Introduction

The aqueous surface cleaning, immersion and unmounting of albumen prints are long held techniques in the craft practice of photographic conservation. The association of albumen photographs with water is a natural one. Albumen photographs are born of water. Photographic processing has always involved the use of aqueous solutions which are followed by prolonged water baths. In particular, the washing of albumen photographs has traditionally been associated with preservation. Nineteenth century albumen printers were very aware of the link between image permanence and extensive post-processing washing in clean water. During the manufacture, albumen photographs often go through several cycles of wetting and drying. Not only are they thoroughly washed, but prints are fixed and toned in aqueous solutions.

In the twentieth century, paper conservation practice often involves the washing of degraded or discolored paper artifacts. After bathing, paper artifacts are often perceived to be whiter, stronger and healthier (Vitale, 1992). As the field of photographic conservation evolved, it naturally adapted techniques and approaches from both paper conservation and from photographic processing.

Evaluation of aqueous treatment of albumen photographs is not new. Alice Swann (1981) made several observations on the detrimental effects of water on albumen photographs. Swan asserted that albumen prints treated with water exhibited an increase in albumen layer cracking, but did not quantify the phenomenon. She

also expressed concern that aqueous treatment seemed to cause an overall "contraction or shrinkage" of the albumen. Though alarming, the aqueous treatment of albumen prints has remained, with some exceptions (Hill, 1991), a traditional technique that remains an accepted practice in photographic conservation.

It appears that the perceived benefits of aqueous treatment of albumen prints currently outweigh the risks. Among the possible benefits: (1) aqueous surface cleaning is a quick and effective means to remove dirt and accretions, (2) aqueous immersion is often a reliable method for removing albumen photographs from degraded, damaged mounts, and (3) the washing of albumen prints will reduce the presence of degradation products in the paper support and may decrease the yellow/brown discoloration in the albumen layer.

The purpose of this research was to assess the benefits of a typical aqueous treatment regime and weigh them against the risks. Print color, gloss and cracking were quantified for twenty albumen photographs. The photographs were then treated by aqueous surface cleaning. Color, gloss and crack width/population measurements were made after this surface cleaning procedure. The photographs were immersed in water and dried. Again, measurements of color, gloss and albumen layer crack width/population were made. It should be noted that the treatment protocol outlined in this paper is not necessarily "standard" since alternative techniques exist for the aqueous cleaning and unmounting of albumen photographs.

2.1 Materials and Methods

2.1.1 Experimental Group

The photographs included in this study typify the mature albumen printing process which was in practice between the mid 1860's and the 1890's. The twenty albumen photographs have a moderate to high sheen. All of the photographs appear to have been coated with albumen by large-scale, commercial manufacturers. For this study, an attempt was made to secure photographs with diverse origins. Of the ten never-mounted prints, seven are by various photographers active in the American west and three originate from the same photographic publishing house located in Paris. The seven American photographs came from the same institutional collection. Of the ten mounted photographs three are German, two are American, two are English, one each is of French, Italian and Spanish origin. All mounted prints are from two private collections. Prints were selected to avoid additional variables such as tinting with aniline dyes and silver mirroring.

2.1.2 Dimensional Characterization

Prior to treatment the photographs were measured along the machine direction and cross-machine direction of the paper base. Albumen thickness was measured by the use of a Leitz Component Measuring Microscope (McCormick-Goodhart, 1989). The measuring technique is straightforward. The top layer of the albumen is brought into focus. The microscope is then focused through the albumen layer to the paper fibers below. The resulting focal length displacement is digitally recorded. This technique is capable of accuracy up to ± 0.3 microns. There is, however, no compensation for the index of refraction of the albumen which makes the albumen coating appear very slightly thinner.

A drawback to this technique, when applied to albumen prints, is the fact that albumen thickness is widely variable across the surface of the same photograph. To help compensate for the irregular nature of the coating, ten measurements of randomly selected areas were made for each photograph. The ten measurements were then averaged.

2.1.3 Characterization of Albumen Cracking

After considering many techniques to quantify albumen cracking, the simplest alternative proved to be the best. A representative area on each photograph was chosen. This area was always well away from the edges of the photograph; areas of abrasion or other damage were avoided. The area (1.1158 mm^2) was

photographed through a microscope at 44.5 X magnification. The film used was Polaroid PolaGraph High Contrast 35mm Film. This film was chosen because the enhanced contrast emphasized crack delineation. The samples were lit with a raking light which was kept constant for all photographs. A polyester template with cut-out openings was created so the areas examined could be returned to after surface cleaning and washing.

The resulting slides were projected onto a smooth, reflective surface. Cracks were measured at their widest point using a ruler in millimeters. To insure the same projected magnification for each slide, a calibration slide was made. The calibration slide showed a micrometer with a measured distance of 0.1 millimeters also at 44.5 X magnification. Prior to making measurements from the projected slides, the magnification on the slide projector was adjusted so that the 0.1 millimeter distance equaled 40.0 millimeters when projected. This technique also had the advantage that each sample had the same conversion: 1 millimeter projected image equaled 2.5 microns of actual distance.

The slides were projected onto the reflective surface in treatment sequence. Characteristic cracks from the first slide were traced on the reflective surface. After measurements were taken, the same cracks in the after treatment slides were superimposed on these markings. This technique insured that the same cracks were measured across the same points before treatment, after surface cleaning, and after immersion. The number of cracks measured, for each photograph, was dependent upon the extent of cracking before treatment. Following treatment the number of cracks had measurably increased, in all but two prints. Only cracks present in the before treatment slides were used to calculate change in crack width. Since new cracks had smaller widths, their incorporation into crack width calculations would have biased the average.

Crack population was calculated as a function of the crack width measurement process. The average number of cracks before treatment was 20.6, based on the 1.1158 mm^2 measured area. Therefore, for a square inch there was an average of 12,000 cracks; for an average 8" X 10" print there were approximately a million cracks.

2.1.4 Characterization of Gloss

Print gloss has always been a defining, essential, photographic attribute. Gloss, with its associated benefits of image sharpness and detail, was very much an aesthetic consideration during the nineteenth century. As the albumen printing process developed, thinly coated albumen prints gradually were replaced by glossier prints with thicker albumen coatings. A further transformation took place as the pictorial aesthetic evolved in the late nineteenth and early twentieth centuries. At that time, matte albumen papers (made with starch or arrowroot added to the albumen) were introduced. These papers comprise the last large-scale commercial production of albumen paper.

As a physical attribute, gloss can also be used to gauge the character of a surface coating. A rough, non-uniform surface will scatter light and appear matte. On the other hand, a smooth, regular surface will reflect incident light resulting in higher reflectance and higher gloss.

Specular gloss measurements were taken with the use of a Dr. Lange Labor Reflektometer using the $60^?$ incident light/reflected light geometry. The ASTM Standard Method D523-85 for specular gloss was followed (ASTM, 1985).

The glossmeter is a relatively simple device. Measurements are based upon the difference between a known quantity of incident light projected by the instrument and the amount of reflected light detected by a photocell within the instrument. These quantities are scaled from 0 to 100.

Three (30 mm^2) areas across the individual photographs were measured. These areas were measured three times each. This process was repeated for a total of three times per photograph. The data were averaged to yield a single, overall gloss measurement for each photograph before treatment, after surface cleaning and after immersion. The resulting data meet the ASTM criteria for reproducibility and repeatability at a 95% confidence interval. Areas of potentially high wear, such as the edges of the photographs or abraded areas were avoided when making measurements. A polyester template with cut-out openings was made for each

photograph so the area measured before treatment could be returned to after treatment.

2.1.5 Characterization of Albumen Print Color

The twenty albumen prints were analyzed for color using a Hunterlab Ultrascan integrating sphere spectrocolorimeter. Diffuse illumination of the sample is achieved with a simulated CIE D65 spectral distribution light source. Data is reported as both spectral reflectance (375nm to 750nm) and in the CIE **L*a*b*** colorimetric scale.

Spectral measurements between 375nm and 750nm were made at 5nm intervals. Data is reported as percent reflectance (%R) of a theoretical white, which is approximated by fresh fumed barium sulfate or microbeads of a solid chlorofluorocarbon (Halon). Measurements were taken in the specular-included (SIN) mode. In planning the experiment, it was anticipated that different colored mounts would influence the color of print highlights. However, during initial trials it was discovered that the specular-included mode virtually eliminated the influence of colored photographic mounts on measurements of albumen print highlights.

Colorimetry was chosen over the more familiar densitometry for a number of reasons. Print color can be correlated to human perception when using colorimetry. Changes in print color due to treatment could, thus, be related to human perception. A difference of 0.2 color units is generally considered to be the limit of perception for the standard observer. Colorimetry also yields spectral reflectance data across the visible spectrum. The colorimeter is more sensitive than the densitometer to changes in light colors, which is similar to human sensitivity. A slight color change in the print highlights could, therefore, be measured more accurately with the colorimeter than with the densitometer (Popson, 1989). Since aqueous treatment was thought to have the greatest potential impact on areas of minimum image density, colorimetry emerged as the measuring tool of preference.

Data from the colorimeter was quantified using the CIE 1976 **L*a*b*** (CIELAB) color scale. The scale is defined by a vertical axis and two intersecting perpendicular axes. The **L*** scale is the vertical axis measuring lightness/darkness. Along the **L*** axis **L***=0 is black, **L***=100 is white. The **a*** scale measures redness-greenness. Positive values for **a*** measure the amount of red; negative values measure the amount of green. Similarly, **b*** values measure the amount of blue or yellow. Positive **b*** values measure the amount of yellow; negative **b*** values measure the amount of blue.

L*a*b* data were gathered for the albumen print maximum density areas, middle density areas and highlights. Polyester templates with cut-out openings were used so the exact area measured (0.375" diameter) before treatment could be measured after surface cleaning and immersion. It was determined that five individual readings for each area was sufficient to produce repeatable results with acceptable standard deviations.

2.2 Experimental Design

Once fully characterized, the twenty photographs were treated. The treatments were designed to best approximate common conservation practice. The experimental philosophy was to follow the effects of a common treatment protocol rather than the independent effects of surface cleaning or immersion. The latter experimental design would have required twice the number of prints if performed at the same level of accuracy.

Note that the data used in a previous report on this work (Messier & Vitale, 1993) have been recalculated. The previous report concentrated only on gauging the width gain of pre-existing cracks. Prior to the current report it was apparent that means existed to gauge the formation of new cracks. This assessment of new crack formation required a repetition of crack measurements for the never-mounted photographs. The current data for crack width increase are lower by approximately 10-12% which is within the 95% confidence intervals previously reported.

The photographs were first surface cleaned with deionized water applied with cotton swabs. After

surface cleaning, the mounted photographs were air dried, while the unmounted photographs were dried between smooth photographic blotters and under weight (0.1 PSI) to minimize print curl. Once dry, color, gloss and crack width and population data were collected again.

The photographs were immersed in baths of deionized water. The never-mounted photographs were immersed for one hour, then transferred to a final bath of fresh deionized water for 15 minutes. Photographs with mounts were immersed until they could be safely separated from their mounts. Length of immersion time varied from approximately one hour to up to four hours. Immersion times were noted, though it became clear that the amount of time spent in water had no correlation to the amount of change measured after treatment. Once unmounted, each photograph was placed in a fresh bath of deionized water for 15 minutes. Following immersion, both sets of mounted and never-mounted photographs were allowed to air dry face-up until the surface gloss was gone (approximately 10-15 minutes). They were then placed between smooth photographic blotters (common conservation practice) and under light pressure (0.1 PSI) until dry. The blotters were changed once after 15 minutes. The photographs remained between blotters for approximately 48 hours before the effect of treatment was assessed. As expected, there was no evidence of the albumen layer adhering to the blotters.

3. Results

3.1 Dimensional Characterization

3.1.1 Albumen Thickness

The average albumen thickness for the group of twenty prints was 13.8 microns. The average thickness for the mounted photographs was 11.2 microns. The average albumen thickness for never-mounted photographs was 16.3 microns. Though the sample populations are far too small to make any firm statistical conclusions, the differences may point to an important trend. The reason albumen layers are less thick in mounted photographs is most likely a result of the mounting process.

Mounting history appears to be an important variable. In large part, albumen prints are mounted to eliminate their strong tendency to curl. Generally, wet prints were mounted with high pressure and, in some cases, heat. The wetting, heat and pressure sustained during mounting is undoubtedly an important variable. Since the mounted photographs tend to have thinner albumen layers, it is probable that the mounting process compresses the print surface, resulting in more even and compact albumen layers.

3.1.2 Overall Dimensional Shrinkage

Measurements taken of the twenty historic albumen prints were compared before and after complete aqueous treatment (see Table 1). These measurements indicate that the group as a whole lost 0.19% in the machine direction and 0.35% in the cross machine direction after aqueous treatment. Mounted and never-mounted photographs behave basically in the same manner (the populations are not distinguishable at a 95% confidence interval). This shrinkage is contrary to the typical dimensional behavior of paper. Paper, after an initial shrinkage (which occurs as a result of the first wetting and drying of the sheet), tends to hold its dimensions except for the small differences due to hysteresis behavior.

TABLE 1
DIMENSIONAL CHANGE OF HISTORIC PRINTS AS A RESULT OF AQUEOUS TREATMENT

	Machine Direction of Paper Base	**Cross-Machine Direction of Paper Base**
MOUNTED PRINTS		
1	-0.06%	-0.30%
2	no data	no data

3	-0.87%	-0.90%
4	-0.29%	-0.61%
5	-0.29%	-0.61%
6	-0.28%	0.00%
7	-0.17%	-0.36%
8	0.13%	-0.25%
9	0.23%	0.10%
10	-0.28%	-0.16%
AVERAGE	-0.19%	-0.31%
C.I.	0.23	0.24
NEVER-MOUNTED PRINTS		
1	-0.74%	-1.75%
2	0.00%	0.26%
3	-0.34%	-0.49%
4	-0.10%	-0.22%
5	-0.10%	0.00%
6	-0.36%	-0.26%
7	0.00%	-0.29%
8	-0.18%	no data
9	-0.06%	no data
10	0.00%	-1.15%
AVERAGE	-0.19%	-0.39%
C.I.*	0.07	0.20
MOUNTED AND NEVER-MOUNTED COMBINED		
AVERAGE	-0.19%	-0.35%
C.I.*	0.13	0.23

* Confidence intervals are calculated at 95% obtained by multiplying the standard error by the *t* value.

3.2 Cracking

3.2.1 Pre-Treatment Cracking

Before treatment, crack width measurements were averaged for each photograph. The crack width average for the total sample group of twenty photographs was 11.7 microns.

Of the twenty photographs examined, sixteen exhibited a crack pattern with a predominant orientation, and four had a random orientation. Of the sixteen photographs with a distinct directional pattern, the cracks ran parallel to the machine direction of the paper primary support in all but two instances. Those two photographs had crack patterns perpendicular to the machine direction of the paper, they had never been mounted, and were among the three photographs which were found tightly rolled along the machine direction of the paper support.

3.2.2 Increased Crack Width Following Treatment

All twenty photographs had wider cracks after surface cleaning and immersion. Of particular interest, crack width increased the same amount due to surface cleaning and immersion. The average crack width increase measured after surface cleaning was 27.1%. Average crack width increase due to immersion following by surface cleaning was an additional 32.6%. Since these numbers are not distinguishable at a 95% confidence level, the extent of crack width increase is independent of these two types of aqueous treatment when performed in succession. It should be noted that tests for the effects of immersion alone were not made; immersion was preceded by surface cleaning. Figure 1 is a series of photomicrographs showing a representative response for one of the photographs in the sample group.

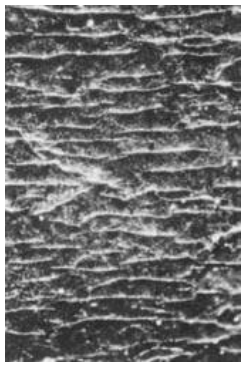


Fig. 1a. Photograph of surface of albumen print. Before treatment. 27x

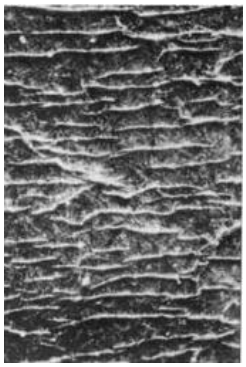


Fig. 1b. Same field after surface cleaning.

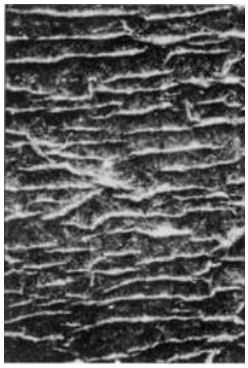


Fig. 1c. Same field after immersion

Table 2 shows the effects of the aqueous treatment on crack width. Data for mounted and never-mounted photographs are presented for the sake of comparison though these two populations are statistically indistinguishable at the 95% confidence level. Note the wide range of change. All of the prints in this study showed an increase in crack width following treatment. Sixteen of the twenty prints have increases in crack width that are significant at the 95% confidence level.

TABLE 2
CRACK WIDTH INCREASE DUE TO AQUEOUS SURFACE CLEANING AND IMMERSION

	Initial Crack Width*	**C.I.****	**Crack Width after Surface Cleaning***	**C.I.****	**Change from Initial Crack Width***	**Crack Width After Immersion***	**C.I.***	**Change From Surface-Cleaned Crack Width***	**Total Crack Width Gain***
MOUNTED PRINTS									
1	17.4	2.7	19.3	2.8	1.9	23.9	3.6	4.6	6.5

					(11%)			(24%)	(38%)
2	3.7	0.7	6.5	1.0	2.8 (77%)	11.3	2.1	4.8 (74%)	7.6 (207%)
3	19.9	5.0	25.0	6.1	5.1 (26%)	31.8	6.7	6.8 (27%)	11.9 (59%)
4	10.0	2.9	13.3	3.0	3.3 (33%)	18.6	6.1	5.3 (40%)	8.6 (86%)
5	9.8	1.9	14.1	2.6	4.2 (43%)	16.6	3.0	2.5 (188%)	6.7 (69%)
6	11.9	2.6	14.3	2.8	2.4 (20%)	17.6	3.2	3.3 (23%)	5.8 (48%)
7	13.7	3.1	17.6	3.4	3.9 (28%)	20.7	3.6	3.1 (18%)	7.0 (51%)
8	16.9	3.0	21.1	1.8	4.2 (26%)	25.7	5.1	4.6 (22%)	8.8 (52%)
9	14.5	2.7	17.2	3.5	2.7 (19%)	20.9	4.1	3.7 (22%)	6.5 (45%)
10	13.6	1.6	17.6	2.7	3.9 (29%)	20.5	1.9	3.3 (19%)	7.3 (53%)
Average	13.2		16.6		3.4 (27%)	20.8		4.2 (25%)	7.7 (58%)
NEVER-MOUNTED PRINTS									
1	8.8	1.1	11.1	1.6	2.3 (26%)	23.2	4.3	12.1 (109%)	14.5 (165%)
2	11.2	1.7	15.1	2.2	3.9 (34%)	18.8	2.4	3.7 (25%)	7.6 (68%)
3	7.7	0.5	11.1	1.4	3.4 (44%)	16.5	1.4	5.3 (48%)	8.7 (113%)
4	7.8	1.8	10.8	1.7	3.0 (39%)	14.6	1.9	3.8 (35%)	6.8 (88%)
5	8.0	2.2	10.5	2.1	2.5 (31%)	15.2	3.7	4.7 (44%)	7.2 (90%)
6	10.1	0.8	12.3	0.8	2.2 (21%)	17.5	2.6	5.2 (43%)	7.4 (73%)
7	9.2	1.5	12.3	1.8	3.1 (33%)	16.9	3.8	4.6 (38%)	7.7 (83%)
8	10.2	1.0	13.8	1.2	3.6 (35%(	18.5	1.6	4.7 (34%)	8.3 (82%)
9	12.3	1.4	15.1	1.3	2.8	18.1	1.8	3.0	5.8

					(23%(			(20%)	(47%)
10	16.5	9.4	18.5	6.8	2.0 (12%)	26.0	9.9	7.5 (41%)	9.5 (57%)
Average	10.2		13.1		2.9 (28%)	18.5		5.5 (42%)	8.4 (82%)
MOUNTED AND NEVER-MOUNTED PRINTS COMBINED									
Average	11.7		14.8		3.2 (27%)	19.7		4.8 (33%)	8.0 (69%)

* in microns

** Confidence intervals are calculated at 95% . They are obtained be multiplying the standard error by the ***t*** value.

3.2.3 Increased Crack Populations

The average number of cracks for all 20 prints increased from 21.7 to 30.6 over an area of 1.1158/mm^2, a 41% increase. Table 3 lists the results for crack population increases. As can be seen, 18 of the 20 prints had increases in population. The range of population increase is from 7.4% to 94.7%. The mounted prints had average crack population increases of 58%, while the never-mounted prints had increases of 82%. Though it appears the mounted prints exhibit a much greater increase in crack population, the size of the sample groups and the number of crack measurements are too small to make any firm statistical conclusions.

TABLE 3
CRACK WIDTH POPULATION INCREASES DUE TO AQUEOUS SURFACE CLEANING AND IMMERSION

	Initial Number of Cracks	**Number of Cracks after Surface Cleaning**	**Increase from Initial Number of Cracks**	**Number of Cracks after Immersion**	**Increase from Surface Cleaned Number of Cracks**	**Total Increase in Number of Cracks**
MOUNTED PRINTS						
1	30	39	9 (30%)	50	11 (28%)	20 (67%)
2	19	26	7 (37%)	37	11 (42%)	18 (95%)
3	27	33	6 (22%)	46	13 (39%)	19 (70%)
4	9	11	2 (22%)	12	1 (9%)	3 (33%)
5	16	21	5 (31%)	26	5 (24%)	10 (63%)
6	21	24	3 (14%)	31	7 (29%)	10 (48%)
7	29	34	5 (17%)	39	5 (15%)	10 (35%)
8	18	24	6 (33%)	30	6 (25%)	12 (67%)
9	24	31	7 (29%)	37	6 (19%)	13 (54%)

10	33	33	0 (0%)	45	12 (36%)	12 (36%)
NEVER-MOUNTED PRINTS						
1	14	15	1 (7%)	18	3 (20%)	4 (29%)
2	25	26	1 (4%)	27	1 (3%)	2 (8%)
3	23	26	3 (13%)	30	4 (15%)	7 (30%)
4	19	20	1 (5%)	25	5 (25%)	6 (32%)
5	15	18	3 (20%)	21	3 (17%)	6 (40%)
6	23	26	3 (13%)	29	3 (12%)	6 (26%)
7	13	14	1 (8%)	18	4 (29%)	5 (39%)
8	27	29	2 (7%)	29	0 (0%)	2 (7%)
9	22	22	0 (0%)	22	0 (0%)	0 (0%)
10	5	5	0 (0%)	5	0 (0%)	0 (0%)
MOUNTED AND NEVER-MOUNTED PRINTS COMBINED						
Average	19.9	23.1	3.2 (16%)	28.0	4.9 (21%)	8.1 (41%)

3.3 Gloss

3.3.1 Pre-Treatment Gloss

The twenty photographs included in this study had an average gloss of 25.1 gloss units. The average gloss for the never-mounted photographs was 24.0 gloss units while the average gloss for mounted photographs was 26.2 gloss units; the two populations can not be distinguished at the 95% confidence level.

3.3.2 Loss of Gloss Following Treatment

Of the 20 prints treated, 15 exhibited a decrease in gloss after complete treatment. The entire group diminished in gloss an average of 3.8 gloss units (-15%); the range of decrease was from -41% to -3%. Surface cleaning alone reduced the gloss in 15 prints and increased the gloss in 5 prints.

The group of five prints that increased in gloss after surface cleaning (never-mounted prints #'s 2, 7, 10, and mounted samples #'s 4 and 6) is not identical to the group of five prints that gained gloss after immersion: two prints which initially gained gloss due to surface cleaning ultimately lost gloss due to the total treatment (never-mounted print #2 and mounted print #4) and two prints which lost gloss due to surface cleaning exhibited an increase in gloss after immersion (never-mounted print #9 and mounted print #10). The range of change for the five prints that gained gloss after the total treatment was 1% to 13% (never-mounted prints #'s 7, 9, 10, mounted prints #'s 6 and 10). In some cases the increases are quite small. All gloss changes in this experiment are statistically significant at the 95% confidence interval (CI).

Table 4 presents the gloss data. Mounted and never-mounted photographs are presented as groups for the sake of comparison, although these two populations are statistically indistinguishable at the 95% confidence level. When immersion follows surface cleaning it appears that immersion has a greater impact than aqueous surface cleaning, but the two populations are statistically indistinguishable at the 95% confidence level.

TABLE 4
CHANGE IN GLOSS DUE TO SURFACE CLEANING AND IMMERSION

	Initial Gloss (in gloss units)	CI*	Gloss after Surface Cleaning (in gloss units)	CI*	Change from Initial Gloss	Gloss after Immersion (in gloss units)	CI*	Change from Surface-Cleaned Gloss (in gloss units)	Total Gloss (in gloss units)
1	15.9	0.08	15.3	0.00	-0.7 (-4%)	13.4	0.02	-1.9 (-12.4%)	-2.5 (-16%)
2	39.3	0.06	37.3	0.05	-2.1 (-5%)	23.1	0.16	-14.2 (-38%)	-16.2 (-41%)
3	22.1	0.06	20.6	0.02	-1.5 (-7%)	16.3	0.05	-4.3 (-21%)	-5.8 (-26%)
4	33.4	0.14	33.4	0.03	0.0 (0%)	32.4	0.11	-1.1 (-3%)	-1.1 (-3%)
5	51.6	0.12	45.3	0.01	-6.3 (-12%)	38.2	0.01	-7.1 (-16%)	-13.4 (-26%)
6	25.3	0.03	27.1	0.04	1.8 (7%)	25.8	0.27	-1.3 (-5%)	0.5 (2%)
7	18.8	0.05	18.5	0.03	-0.3 (-2%)	16.7	0.04	-1.8 (-10%)	-2.1- (11%)
8	14.4	0.05	14.3	0.00	-0.1 (-1%)	13.9	0.03	-0.4 (-3%)	-0.5 (-4%)
9	20.6	0.16	20.4	0.02	-0.3 (-1%)	18.9	0.79	-1.4 (-7%)	-1.7 (-8%)
10	20.3	0.01	19.7	0.02	-0.6 (-3%)	20.6	0.04	0.9 (5%)	0.3 (1%)
Average	26.2		25.2		-1.0 (-4%)	21.9		-3.3 (-13%)	-4.3 (-) 6%
NEVER-MOUNTED PRINT									
1	63.3	0.11	60.7	0.13	-2.6 (-4%)	38.8	0.11	-21.9 (-36%)	-24.5 (-39%)
2	16.0	0.07	15.0	0.04	-1.0 (-6%)	14.1	0.01	-0.8 (-6%)	-1.8 (-12%)
3	15.0	0.11	16.4	0.04	1.4 (9%)	13.9	0.01	-2.4 (-15%)	-1.0 (-7%)
4	19.0	0.21	18.4	0.03	-0.6 (-3%)	15.8	0.08	-2.7 (-14%)	-3.2 (-17%)
5	16.7	0.07	16.1	0.03	-0.6 (-4%)	14.6	0.01	-1.4 (-9%)	-2.0 (-12%)
6	17.6	0.07	16.6	0.03	-1.1	15.5	0.02	-1.0	-2.1

					(-6%)			(-6%)	(-12%)
7	17.2	0.04	17.6	0.03	0.4 (2%)	18.0	0.02	0.4 (2%)	0.8 (5%)
8	26.1	0.04	21.3	0.03	-4.8 (-18%)	21.4	0.45	0.1 (0%)	-4.7 (-18%)
9	26.1	0.04	25.7	0.23	-0.4 (-1%)	29.3	0.05	3.6 (14%)	3.2 (12%)
10	23.2	0.14	24.0	0.06	0.8 (3%)	26.1	0.01	2.2 (9%)	2.9 (13%)
Average	24.0		23.2		-0.8 (-4%)	20.8		-2.4 (-10%)	-3.3 (-14%
MOUNTED AND NEVER-MOUNTED PRINTS COMBINED									
Average	25.1		24.2		-0.9 (-4%)	21.3		(2.8 -12%)	-3.8 (-15%

* in gloss units

** Confidence intervals are calculated at 95%. They are obtained be multiplying the standard error by the ***t***value.

In Figure 2 the results for total change in gloss are compared to initial gloss. Using standard linear regression mathematics an interesting correlation can be made ® = 0.84). The graph indicates photographs with a large amount of gloss have a high probability of losing gloss, while prints with low gloss tend to lose relatively smaller amounts of gloss after treatment.

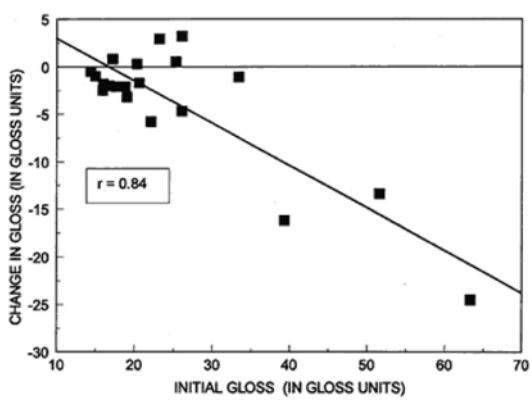


Fig. 2. Correlation between initial gloss and change in gloss

3.4 COLOR

3.4.1 COLOR PRIOR TO TREATMENT

Tables 5, 6 & 7 show the average **L*a*b*** values for the entire sample group before treatment. On average the albumen print highlights are lighter, more yellow, and less red than middle and maximum density

areas, which is to be expected.

3.4.2 COLOR CHANGE: MAXIMUM DENSITIES

There are no statistically significant changes in the data before and after treatment, when the 20 prints are averaged. However, as shown at the bottom of Table 5, many individual prints do show statistically significant changes in the maximum density areas as a result of complete treatment. The summery at the bottom of Table 5 lists the number of prints that were affected by aqueous treatment and average amount of change in **L*a*b*** units. The majority of maximum density areas were lighter, more red and more yellow after aqueous treatment. Eleven of the twenty (55%) were measurably lighter than before treatment; thirteen (65%) were slightly more red; and seventeen were more yellow (85%) after treatment.

TABLE 5
COLORIMETRIC RESULTS FOR MAXIMUM DENSITIES

	BEFORE TREATMENT			SURFACE CLEANED			AFTER IMMERSION		
L*	a*	b*	L*	a*	b*	L*	a*	b*	
1	36.98	5.32	3.55	36.86	***5.37***	***3.62***	37.36	5.52	3.96
2	41.16	7.61	8.67	***41.16***	***7.59***	8.58	***40.99***	8.22	9.38
3	38.19	6.42	6.19	***39.56***	6.54	6.50	40.20	***6.41***	6.65
4	34.30	5.59	2.57	***34.08***	5.94	3.74	***33.73***	6.16	3.87
5	37.06	6.01	3.80	37.17	***6.06***	***3.81***	37.34	6.37	4.48
6	50.72	5.22	11.36	***49.74***	***5.32***	10.69	48.89	5.78	***11.33***
7	61.81	6.59	21.29	63.21	6.41	21.53	***63.11***	6.98	22.24
8	33.61	5.44	2.58	34.04	5.29	1.85	***36.56***	4.78	3.89
9	36.40	4.61	3.44	36.17	4.70	3.52	34.41	5.08	1.94
10	37.07	5.71	3.32	***37.47***	5.73	3.20	37.58	6.00	3.72
Average	40.73	5.85	6.68	40.95	5.90	6.70	41.02	6.13	7.15
NEVER-MOUNTED PRINTS									
1	32.57	6.65	***3.36***	32.66	6.66	***3.49***	32.27	6.70	3.66
2	36.45	7.77	4.98	34.89	7.63	4.33	37.00	7.97	5.78
3	37.01	5.49	4.30	35.94	5.42	4.04	36.70	5.58	4.61
4	47.78	8.16	11.05	47.46	8.25	11.31	47.96	8.42	12.16
5	49.58	9.50	11.93	49.83	9.39	12.00	50.22	9.24	11.99
6	31.34	5.69	1.53	31.30	***5.68***	1.64	31.89	5.81	1.89
7	37.76	7.10	2.36	38.26	6.67	1.88	38.31	6.74	2.45
8	34.07	4.96	2.71	33.60	4.83	***2.69***	33.56	4.80	2.87
9	40.32	4.31	3.95	39.97	4.30	4.07	40.33	4.23	4.47
10	38.46	4.86	6.58	38.99	***4.85***	7.33	***39.07***	4.84	7.31

Average	38.53	6.45	5.28	38.29	***6.37***	5.28	38.73	6.43	5.72
MOUNTED PRINTS AND NEVER-MOUNTED PRINTS COMBINED									
Average	39.63	6.15	5.98	39.62	6.13	5.99	39.87	6.28	6.43

	#	**L***	#	**a***	#	**b***
NUMBER OF PRINTS EXHIBITING AN INCREASE	11	+0.92 units	12	+0.31 units	18	+0.56 units
NUMBER OF PRINTS EXHIBITING A DECREASE	4	-0.78 units	7	-0.26 units	1	-0.50 units
NUMBER OF PRINT THAT WERE NOT AFFECTED	5		1			1

Shaded cells=no change @95% confidence level as compared to before-treatment data
Confidence intervals are calculated at 95% . They are obtained be multiplying the standard error by the ***t***value.

3.4.3 Color Change: Middle Densities

There are no statistically significant changes in the data after treatment when the 20 prints are averaged. However, Table 6 shows that most individual prints show statistically significant changes as a result of treatment. The majority of middle density areas were lighter, more red and more yellow after aqueous treatment. Twelve of the twenty (60%) were measurably lighter than before treatment; 11 (55%) were slightly more red; and 14 were more yellow (70%) after treatment. The summery at the bottom of Table 6 shows the number of prints that were affected by aqueous treatment and average amount of change in **L*a*b*** units for middle density areas. Nine of the eleven prints that were more red after complete treatment were mounted prior to treatment. Of these nine mounted photographs the average **a*** gain was 0.52 units. Following surface cleaning, only 1 mounted photograph was more red, five were unchanged and four were slightly less red. For the two never-mounted photographs the average **a*** gain was an imperceptible 0.06 units. These results are consistent with data reported in section 3.4.4 for print highlights.

TABLE 6
COLORIMETRIC RESULTS FOR MIDDLE DENSITIES

	BEFORE TREATMENT			**SURFACE CLEANED**			**AFTER IMMERSION**		
L*	**a***	**b***	**L***	**a***	**b***	**L***	**a***	**b***	
MOUNTED PRINTS									
1	58.98	5.37	14.59	***59.12***	***5.37***	14.70	***59.60***	5.90	15.43
2	52.07	6.80	14.41	***52.23***	***6.81***	***14.34***	***52.21***	7.46	14.70
3	69.81	4.49	12.74	69.79	4.44	12.90	71.33	4.25	13.67
4	56.20	4.29	8.48	56.51	***4.30***	8.22	56.84	4.64	9.67
5	65.16	3.54	12.56	***65.65***	3.41	12.22	66.44	4.17	14.08
6	71.49	2.67	23.80	***71.48***	2.75	23.69	72.27	3.32	25.25
7	71.60	3.78	22.36	73.89	3.70	22.83	73.98	4.36	23.81
8	60.42	4.62	11.35	***60.97***	***4.49***	***11.40***	49.13	4.94	6.34

9	49.37	4.72	5.96	50.26	***4.75***	6.07	62.52	5.27	12.63
10	65.73	4.80	13.84	66.10	***4.80***	***13.80***	66.91	5.19	14.66
Average	62.08	4.51	14.01	62.60	4.48	14.02	63.12	4.95	15.02
NEVER-MOUNTED PRINTS									
1	66.12	5.34	13.06	66.56	5.27	13.15	65.69	5.22	12.33
2	58.83	5.89	9.47	58.65	5.91	9.60	58.87	6.01	9.99
3	70.35	3.36	14.48	70.15	3.44	14.53	70.18	3.41	13.65
4	62.54	7.18	18.81	62.58	7.15	19.16	62.28	7.18	19.63
5	63.02	6.36	12.90	63.90	6.17	12.82	63.19	6.31	12.71
6	83.17	2.18	14.97	83.98	2.06	14.78	83.87	1.98	14.24
7	80.24	3.03	22.55	80.63	2.84	22.31	***79.88***	2.78	21.65
8	80.13	1.97	12.64	***80.11***	1.82	12.84	79.86	1.67	13.02
9	76.95	2.17	11.80	77.13	2.03	11.96	76.61	2.01	12.26
10	72.32	2.43	18.51	72.20	2.51	18.79	72.74	2.39	18.67
Average	71.73	3.99	14.92	71.59	3.92	14.99	71.32	3.90	14.82
MOUNTED PRINTS AND NEVER-MOUNTED PRINTS COMBINED									
Average	66.72	4.25	14.46	67.09	4.20	14.51	67.22	4.42	14.92

	#	**L***	#	**a***	#	**b***
NUMBER OF PRINTS EXHIBITING AN INCREASE	12	+0.92 units	11	+0.40 units	14	+0.83 units
NUMBER OF PRINTS EXHIBITING A DECREASE	5	-0.30 units	8	-0.17 units	6	-0.68 units
NUMBER OF PRINT THAT WERE NOT AFFECTED	3		1		0	

Shaded cells=no change @95% confidence level as compared to before-treatment data
Confidence intervals are calculated at 95%. They are obtained be multiplying the standard error by the ***t***value.

3.4.4 Color Change: Highlights

Complete aqueous treatment generally did not decrease the characteristic yellowing of the albumen print highlights. This finding is considered to be the most important result of the color analysis. As with the maximum density data, no statistically significant changes occurred in the highlights when the entire population is averaged.

However, as summarized at the bottom of Table 7, most individual photographs showed measurable changes after complete treatment. The majority of the highlights were lighter, less red and more yellow after aqueous treatment. Sixteen of the prints (80%) were measurably lighter; eleven prints (55%) were slightly less red; and fourteen prints (70%) appeared more yellow in the highlights. As with the middle and maximum density data, gains in lightness and amount of yellow can be attributed to an initial removal of dirt during surface cleaning then followed by a subsequent removal of dirt trapped in cracks during immersion.

For all twenty prints, highlight areas were either less red or equally red after surface cleaning. After immersion, highlights in every never-mounted print were less red after treatment while highlights in 9 out of 10 mounted prints were more red after treatment. As with the medium density data, immersion produced distinctly different results based upon whether or not the photograph was mounted. The data point to the possibility that soluble degradation products in albumen print mounts alter the color of the highlights and middle density areas during immersion

Table 7 presents all colorimetric results for the minimum density areas measured before treatment, after surface cleaning and after immersion. Note the relatively large gains for the **a*** value for mounted prints after immersion.

TABLE 7
COLORIMETRIC RESULTS FOR HIGHLIGHTS

	BEFORE TREATMENT			**SURFACE CLEANED**			**AFTER IMMERSION**		
L*	**a***	**b***	**L***	**a***	**b***	**L***	**a***	**b***	
NEVER-MOUNTED PRINTS									
1	79.59	2.74	20.53	***79.56***	2.73	20.36	80.99	3.34	21.49
2	80.54	2.20	21.98	80.73	***2.17***	21.76	82.15	2.98	23.03
3	86.17	1.22	11.92	86.38	1.15	11.85	87.60	0.82	12.38
4	82.18	-0.39	11.57	***82.19***	-0.41	***11.45***	83.56	-0.08	13.28
5	81.16	0.93	16.89	***81.22***	***0.95***	***16.76***	83.37	1.98	19.49
6	78.44	0.82	19.24	78.29	***0.84***	19.01	80.31	1.41	21.25
7	77.35	2.69	20.87	78.98	2.63	21.20	79.49	3.32	22.22
8	75.34	0.68	15.07	74.89	***0.75***	14.81	76.80	1.72	16.85
9	78.23	1.98	14.72	79.49	1.90	***14.93***	80.84	2.06	16.13
10	84.73	0.87	17.52	85.11	***0.83***	17.14	86.68	1.31	18.29
Average	80.37	1.37	17.03	80.68	1.35	16.93	82.18	1.89	18.44
MOUNTED PRINTS									
1	78.13	2.50	14.52	78.24	2.42	14.47	78.27	2.31	13.96
2	87.60	1.51	14.41	87.86	1.41	14.20	87.69	1.41	13.14
3	75.96	3.11	18.11	76.19	3.06	18.40	76.38	3.07	***18.07***
4	81.70	3.36	23.96	81.75	3.34	24.04	81.49	3.22	24.74
5	86.90	0.90	15.81	86.33	0.84	15.88	86.29	0.82	15.15
6	88.90	0.88	14.14	***89.46***	0.77	***14.15***	***89.68***	0.67	13.35
7	85.30	1.74	20.26	85.15	1.71	20.17	85.21	1.55	19.42
8	84.95	1.00	9.52	85.05	0.82	9.79	85.20	0.52	10.27
9	85.30	0.82	7.67	85.18	0.69	7.94	85.53	0.34	8.26

10	83.26	0.08	8.99	83.09	0.02	9.14	83.41	-0.10	9.34
Average	83.80	1.59	14.74	83.83	1.51	14.82	83.92	1.38	14.57
MOUNTED PRINTS AND NEVER-MOUNTED PRINTS COMBINED									
Average	82.09	1.48	15.89	82.26	1.43	15.87	83.05	1.63	16.51

	#	L*	#	a*	#	b*
NUMBER OF PRINTS EXHIBITING AN INCREASE	16	+1.21 units	9	+0.64 units	14	+0.95 units
NUMBER OF PRINTS EXHIBITING A DECREASE	3	-0.30 units	11	-0.22 units	5	-0.82 units
NUMBER OF PRINT THAT WERE NOT AFFECTED	1		0		1	

Shaded cells=no change @95% confidence level as compared to before-treatment data
Confidence intervals are calculated at 95% . They are obtained be multiplying the standard error by the ***t***value.

Table 8 shows the **averaged spectral reflectance** of the individual albumen prints, in the highlight region, after surface cleaning and then after immersion. The data are obtained by averaging the 75 individual spectral measurements taken every 5nm from 375nm to 750nm, using the equation $(dR/R_0)100$ where R_0 is the percent reflectance before treatment and dR is the change in percent reflectance due to treatment. With the exception of never-mounted sample #9, surface cleaning generally produces relatively small percentage increases in reflectance for both never-mounted and mounted photographs. The increase in reflectance is attributed to the removal of dirt because, in all cases, the swabs used in surface cleaning were visibly soiled after treatment. The data also indicate that when immersion follows surface cleaning there is an additional increase in reflectance.

When data for individual prints are compared within groups (with the exception of never-mounted print #9) there is a fairly uniform increase in reflectance due to both surface cleaning and immersion. Whether or not a print is mounted appears to influence the changes in reflectance due to dirt removal, although it is not known if the mounted prints were "dirtier" than the never-mounted prints.

TABLE 8
AVERAGE % CHANGE IN REFLECTANCE ACROSS THE VISIBLE SPECTRUM FOR ALBUMEN PRINT HIGHLIGHTS

	CHANGE IN	CHANGE IN		TOTAL		
NEVER	REFLECTANCE	REFLECTANCE		CHANGE IN		
MNTD.	FOLLOWING	FOLLOWING				
PRINTS	S-CLEAN	CI**	IMMERSION	CI**	REFLECTANCE	CI**
MOUNTED PRINTS						
1	-0.05%	0.07	4.60%	0.32	4.55%	0.29
2	0.59%	0.10	4.65%	0.36	5.26%	0.30
3	0.63%	0.09	3.24%	0.10	3.98%	0.12

4	0.07%	0.09	3.41%	0.45	3.48%	0.39
5	0.26%	0.10	5.67%	0.74	5.94%	0.69
6	-0.23%	0.16	5.79%	0.61	5.54%	0.51
7	5.19%	0.11	1.88%	0.42	7.16%	0.41
8	-1.05%	0.13	7.10%	0.95	5.98%	0.99
9	3.88%	0.09	3.64%	0.25	7.66%	0.29
10	1.36%	0.18	4.60%	0.26	6.02%	0.21
NEVER-MOUNTED PRINTS						
1	0.26%	0.09	0.38%	0.25	0.64%	0.26
2	0.71%	0.10	0.26%	0.42	0.98%	0.46
3	0.41%	0.18	0.95%	0.19	1.36%	0.13
4	0.03%	0.11	-1.42%	0.31	-1.38%	0.38
5	0.19%	0.15	0.28%	0.31	0.46%	0.26
6	1.45%	0.12	1.04%	0.34	2.50%	0.34
7	-0.45%	0.12	0.58%	0.30	0.12%	0.29
8	-0.11%	0.19	-0.05%	0.13	-0.16%	0.24
9	28.83%	1.90	0.56%	0.18	29.57%	2.00
10	-0.80%	0.17	0.64%	0.22	-0.17%	0.20
AVERAGES WITHOUT NEVER-MOUNTED 9						
Mounted Average	1.06%	1.47	4.46%	1.13	5.55%	0.67
Never-Mounted Average	0.19%	0.53	0.29%	0.59	0.48%	0.89
Combined Average	0.65%	0.75	2.49%	1.20	5.02%	3.14
AVERAGES INCLUDING NEVER-MOUNTED 9						
NEVER MOUNTED AVERAGE	3.05%	6.84	0.32%	0.52	3.39%	6.98
COMBINED AVERAGE	2.06%	3.11	2.39%	1.16	4.47%	3.13

**Confidence intervals are calculated at 95%, obtained by multiplying the standard error by the *t* value.

Figures 3 and 4 show the averaged spectral reflectance curves for the highlights of the group of never-mounted and the group of mounted photographs. Due to the wide variation of color within these two groups, the differences are not statistically significant at a 95% confidence level (this finding is in agreement with the previously reported **L*a*b*** results). Figures 3 and 4, however, provide useful visualizations of the effects of

treatment. As indicated by the graphs, aqueous treatment results in generally uniform increases in reflectance across the visible spectrum.

An exception is the disproportionate large increases in reflectance in the yellow/orange/red end of the spectrum resulting from immersion of mounted prints. The majority of this increase occurs above 580 nm. Prior to 580 nm, the percent increase is 4.7%. After 580 nm, there is a 6.9% increase. Since the increase is uneven across the spectrum, the proportionately higher increase in yellow/orange/red reflectance can not be attributed to the removal of dirt. Again, as the colorimetric data shows, there is evidence that highlights of mounted prints are more red after immersion.

Also of note is the very pronounced trough feature in the curve for the never-mounted prints which runs from 525nm to 625nm. Less reflectance in this region indicates that the never-mounted photographs are less yellow than the mounted prints. This conclusion is in agreement with the colormetric **b*** data presented in Tables 5, 6 and 7).

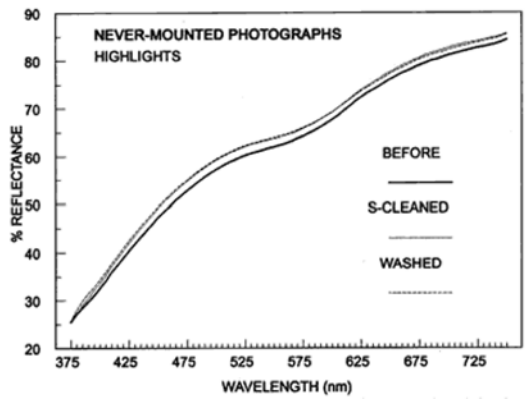


Fig. 3. Average spectral response for the highlights of never-mounted photographs--before treatment, after surface cleaning, and after surface cleaning followed by immersion.

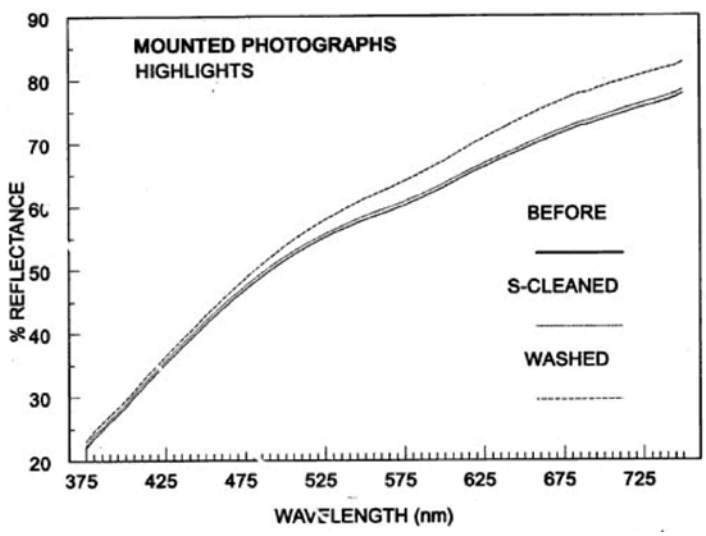


Fig. 4. Average spectral response for mounted photograph highlights--before treatment, after surface cleaning, and after surface cleaning followed by immersion.

4. Discussion

4.1 Note on Use of Blotters

Change in gloss due to contact of wet prints with blotter paper merits consideration. Blotters were used

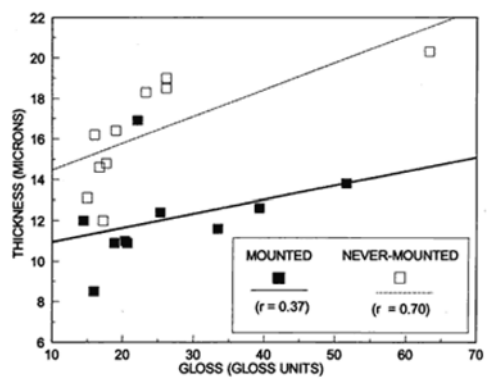
in this experiment following common treatment protocol. The results of the experiment indicate the effect of blotters on gloss appears to be minimal. Table 4 shows even though blotters were not used on the mounted prints after surface cleaning, loss of gloss is exactly the same for the air-dried and blotter dried samples. It can be concluded, therefore, that the of use blotters had no effect in altering gloss.

A possibility also exists that immersion causes a greater degree of swelling and softening of the albumen as compared to surface cleaning. If the albumen layer is softened substantially more by immersion then the surface of the albumen layer could be altered by the use of blotters during drying. However, there was no overt evidence of this effect observed during the project. Cumulative treatment experience indicates that the surfaces of wet, historic albumen prints never stick to blotters during drying.

In Vitale & Messier (1994) the literature concerning Ag^+ hardening of the albumen layer during sensitization is reviewed. Though not quantified, the historical and anecdotal information from albumen print makers affirm that sensitized albumen layers are reasonably tough when wet. These observations, taken with the heavy metal sequestering action of the sulfhydryl groups and pendant oxygen and nitrogen suggest that Ag^+ sequestering is the probable cause of the "hardened" behavior.

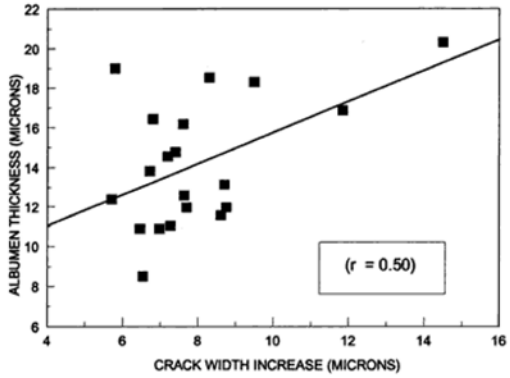
4.2 Integration of Results

When the initial gloss of all 20 prints are averaged there is no link between gloss and albumen thickness. This fact contradicts the accepted wisdom that thicker albumen coatings yield a glossier surface. When the mounted and never-mounted photographs are considered as separate populations a relationship emerges. Figure 5 shows that thicker albumen coatings result in a glossier prints within mounted or never-mounted groups. The low r values ® = 0.70 for never-mounted photographs, r=0.37 for mounted photographs) reflect the fact that the data are from historical artifacts which have numerous variables built-in during manufacture and that other variables that can intervene over time. Such variables could include number of wet/dry cycles during processing, amount of heat and pressure used during mounting, subsequent storage conditions, as well as amount of surface dirt, mechanical abrasion, and albumen cracking.



Relationship between albumen thickness and initial gloss.

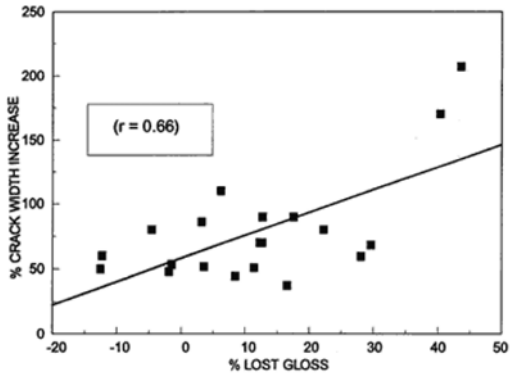
Figure 6 shows the relationship between albumen thickness and crack width increase. Though logical to assume such a relationship exists, the presence of other variables appear to deter a stronger relationship. The plot ® = 0.50) suggests that thicker albumen coatings generally exhibit a greater degree of cracking after aqueous treatment. However, deviation of individuals from the plotted regression (mean) suggests the unknown histories of individual prints plays an important factor.



Relationship between albumen thickness and crack width increase.

Figure 7 shows the relationship between albumen crack width increase and loss in gloss. Undoubtedly surface cleaning removes dust particles and loosely imbedded particles which would scatter light and this change results in some increase in gloss. It is also reasonable to expect that immersion frees up additional particles which are lodged between cracks in the albumen layer. The switching of the 2 prints into the gloss-increased group after their gloss had decreased slightly during surface cleaning (as noted in section 3.3.2) is most likely explained by the opposing effects of crack width increase which decreases gloss and dirt removal which increases gloss. It must be noted, however, that the prints with increases in gloss do not correspond to those prints which show substantial increase in highlight lightness, **L*** (see Table 7). Factors other that dirt removal must contribute to increase in gloss.

Gloss decrease would appear to be due to the massive, 69%, increase in crack width and the 41% increase in crack population. The average crack expands from 11.7 µm to 19.7 µm, and this occurs for an average of 1,000,000 cracks in an 8" X 10" print. Based on an 8" X 10" print, there are an average 410,000 additional cracks. Several practical factors must also contribute to increased light scattering, such as: (1) the albumen segments between cracks probably curl up after wetting and drying (as illustrated in environmental scanning electron microscope experiment shown in Messier & Vitale, 1993) thereby deflecting light, and (2) the artifacts used for the study have unknown manufacture and storage histories.



Relationship between % crack width increase and % lost gloss.

Statistical relationships plotted in this research use standard linear least squares regression mathematics to create a best fit line (Lotus 123®, Release 3.1). The use of linear regressions was chosen for the sake of uniformity. Since the sample populations are relatively small, use of other types of regression calculations seemed unwarranted. It should be noted, however, that the existence of logarithmic or exponential relationships should not be ruled out, especially when there are limiting factors.

4.3 Interpretation of Color Results

Slight color changes were measured in the image highlights, medium density and maximum density

areas. These changes are primarily attributable to the removal of dirt. A layer of dirt behaves much like a neutral-density filter; each wavelength in the visible spectrum receives a slight boost in reflectance when it is removed. The slight increases in all three of the CIE **L*a*b*** parameters, **L*** lightness, **a*** redness and **b*** yellowness, should be interpreted as an increase resulting from a slight increase in reflectance for all wavelengths. One can not observe an increase in yellowness and redness while ignoring the increase in lightness. The increases in both spectral reflectance and CIE **L*a*b*** are congruent.

The relatively large gains in spectral reflectance after 500 nm for the mounted prints (Figure 4) is statistically significant, as is the CIE **L*a*b*** data for some of the prints (summarized in Tables 5, 6 & 7). Mounts used for albumen prints are often paperboard with paper exteriors and a core of unrefined wood pulp material. Since this ligneous core often turns reddish-brown, it is not unreasonable to assume that solubilized reddish-brown material diffuses into the print during the prolonged soaking necessary to remove a print from its mount. The color probably diffuses to the paper support since the solubilized material is compatible with paper.

Though proteins are slowly soluble in water, the fact that the after-treatment curves in Figures 3 & 4 are similar in shape to the before-treatment curves indicates that no major chromophoric components were removed during a 1 to 4 hour immersion. If that were the case, the after treatment curve would have a pronounced dip in the yellow region or bump in the blue region (for example) corresponding with the reflectance of the material removed.

4.4 Summary of Results

Albumen Thickness

- Mounted prints have thinner albumen layers than never-mounted prints.

Print Dimensions

- Most albumen photographs shrink in both the machine and cross-machine direction.

Gloss

- Within groups of mounted or never-mounted photographs, prints with thicker albumen layers are glossier.
- Gloss of albumen prints is reduced by aqueous treatment.
  - All prints had gloss changes after complete treatment.
  - Most prints had a decrease in gloss after complete treatment.

Crack Width

- All albumen prints had pre-existing cracks in the albumen layer.
- Existing cracks in the albumen layer are wider following aqueous treatment.
  - Crack width increase was independent of the type of aqueous treatment, when surface cleaning preceded immersion.

Crack Population

- Crack population increases after aqueous treatment.

Color

- Complete aqueous treatment increased lightness, yellowness and redness for many individual prints.

- Overall, aqueous treatment had no effect on improving albumen print discoloration.
  - Highlights show no decrease in yellow discoloration.
  - Highlights and middle density areas are more yellow/orange/red after immersion.

5. Conclusions

This research demonstrates that the aqueous treatment of albumen photographs has serious consequences. Pre-existing cracks in albumen photographs are measurably wider after treatment and There are additional cracks after treatment. Print gloss is reduced after treatment. Print color, particularly highlight yellowing, is not improved by aqueous treatment. Removal from a mount by aqueous immersion appears to result in some transfer of soluble colored material from the mount to the print.

A practicing conservator must judge the potential merits of the aqueous treatment of albumen prints against the drawbacks. It is clear that application of water to the surface of albumen photographs causes damage. Though this damage is largely on a microscopic level, it is visually perceptible in terms of reduced gloss. In many cases this damage may be acceptable, if a greater preservation aim is served. The aqueous surface cleaning of an extremely soiled print, for example, may be an instance when the benefit of greater image clarity outweighs the damage created by increased overall cracking.

Aqueous treatment of albumen prints should no longer be considered routine or non-invasive. The benefits and risks of aqueous treatment need to be assessed for each individual albumen photograph prior to treatment. Alternatives to aqueous treatment, such as surface cleaning with solvents or crumbled eraser particles, warrant investigation. These alternatives may also have potential hazards. The use of polar solvents may cause excessive swelling and rapid evaporating solvents may result in dramatic dimensional changes. The use of eraser particles may cause abrasion and there is the risk of leaving particles in existing albumen cracks. Further work is needed to develop and assess non-aqueous treatment alternatives for albumen prints.

References

The American Society for Testing and Materials. 1985. Standard test method for specular gloss, Designation D 523-85.

Hill, G. 1991. The conservation of a photograph album at the National Archives of Canada. *Journal of the American Institute for Conservation*. 30: 75-88.

Messier, P.A. & Vitale, T.J. 1993. Cracking in albumen photographs: an ESEM investigation. *Microscopy Research and Technique*. 25: 374-383.

Messier, P.A. & Vitale, T.J. 1993. Albumen photographs: effects of aqueous treatment and fundamental physical properties. Conference proceeding from *The Imperfect Image: Photography, Past, Present and Future*. Centre for Photographic Conservation, London. In press.

Messier, P.A., 1991. The protein chemistry of albumen photographs. *Topics in Photographic Preservation*. 4: 124-135.

McCormick-Goodhart, M. 1989. Research on collodion glass plate negatives: coating thickness and FTIR identification of varnishes. *Topics in Photographic Preservation*. 3: 135-150.

Popson, S. 1989. A comparison of densitometers, reflectometers, and colorimeters. *Tappi Journal*. March: 119-122.

Swan, A. 1981. Conservation of photographic print collections. *Library Trends*. 30: 267-96.

Vitale, T.J. & Messier, P.A. 1993. Physical and mechanical properties of albumen photographs. *Journal of the American Institute for Conservation,* in press.

Vitale, T. J. 1992. Effects of water on the mechanical properties of paper and their relationship to treatment of paper. *Proceedings of the Materials Research Society, San Francisco meeting. Spring 1992*: in press.

Vitale, T. J. 1992. Comparison between practitioner sensory evaluation and measured properties of historic papers before and after washing. AIC annual meeting, Buffalo, 1992. Abstract in preprints.

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